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THE

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## NORMAL AND PATHOLOGICAL,

## HUMAN AND COMPARATIVE.

*CONDUCTED BY*

SIR GEORGE MURRAY HUMPHRY, M.D., LL.D., D.Sc., F.R.S.,

PROFESSOR OF SURGERY, LATE PROFESSOR OF ANATOMY IN THE UNIVERSITY OF CAMBRIDGE.

SIR WILLIAM TURNER, M.B., LL.D., D.C.L., D.Sc., F.R.S.,

PROFESSOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH;

AND

J. G. M'KENDRICK, M.D., LL.D., F.R.S.,

PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE UNIVERSITY OF GLASGOW.

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# Journal of Anatomy and Physiology.

## THE INFLUENCE OF FUNCTION, AS EXEMPLIFIED IN THE MORPHOLOGY OF THE LOWER EXTREMITY OF THE PANJABI.

By R. HAVELOCK CHARLES, M.D., M.Ch., F.R.C.S.I., F.Z.S., *Professor of Anatomy, Medical College, Lahore; Surgeon-Captain, Bengal Medical Service; Surgeon, Mayo Hospital, Lahore; Fellow of the Panjab University.*

THE influence exercised by pressure and posture in producing modifications in the skeleton has on several occasions been discussed in this *Journal*, and I may especially refer to papers by Mr W. Arbuthnot Lane, Sir W. Turner, and Mr Arthur Thomson[1] on this subject.

As further illustrations of the changes in structure that function may bring about, the morphological differences observed between certain bones of the lower extremity of the Panjabi and European are of much interest. The European sits upon a chair, and cannot adopt, save at great inconvenience, the squatting posture generally assumed by the Oriental. Fig. 1 illustrates the position in question, which is customary to the native, whether in field labour, or engaged in culinary operations, or pursuing the avocations of an artisan. He can sleep as comfortably in this as in the supine posture. The position—sartorial—figured in fig. 2 is alike commonly used.

The joints where changes, due to increased mobility, would naturally be observed are, the hip, the knee, and the ankle. In each of these articulations, in the great majority of Panjabi skeletons may be seen exemplified the points referred to in this paper, and illustrated by the accompanying figures.

The positions in question are adopted by males and females

[1] *Jour. of Anat. and Phys.*, vols. xxi., xxii., xxiii., xxiv.

alike, and consequently the peculiarities are observed in the bones of both sexes. There is no restriction as to the sitting posture amongst Panjabi women like that mentioned by Mr Arthur Thomson (quoting Dr St John Brooks)—*Jour. of Anat. and Phys.*, vol. xxiv. p. 211—as holding amongst Zulu females.

In the squatting posture shown in fig. 1, the back of the thigh

Fig. 1.

rests upon the calf, the front of the tuber ischii being in close apposition with the heel; in fact the trunk weight is supported by the heels, the extreme flexion of the hip, knee, and ankle allowing of this. The heels are apart about the distance that separates the ischial tuberosities. The toes are turned outwards. I agree with Mr Arthur Thomson (*Jour. of Anat. and*

*Phys.*, vol. xxiii. p. 623) in thinking that the increase in convexity of the external condylar surface of the tibia much facilitates the consequent movement of the external semilunar cartilage down and back, ensuring safety to the joint. The extreme flexion of the knee is rendered easy, not only by this, but also, as I shall point out, by a greatly increased articular area on the *upper* surface of the internal condyle of the femur (fig. 4), which is received upon the internal condylar surface of

Fig. 2.

the tibia. The latter is a very oblique plane, sloping down from the tibial spine (fig. 6). The position of this plane is partly due to the slanting manner in which the upper epiphysis is set upon the shaft, and in part to the backward curve of the upper portion of the tibial diaphysis. The amount of the backward curve varies, but it is distinctly seen in all, and is made specially obvious when compared with the bone of an European.

I have no doubt but that it is due to the habit of extreme flexion of the joint, acting from the earliest childhood. The ligament of the patella has its attachment to the diaphysis. In complete flexion, before the junction of the epiphysis to the shaft, the tension of the ligament posteriorly upon the front of the former would have a tendency to push it backwards. I do not agree with Dr Collignon ("Description des Ossements fossiles humains," *Revue d'Anth.*, vol. ix., Paris, 1880), who thinks that when tibiæ present the obliquity noted, it is probable the gait of the individual was less erect than ordinary. The gait of the Panjabi is as erect as that of a guardsman! He, however, either has acquired, or inherited, a knee-joint of greater flexibility than that of the European, and the morphological elements of the joints have been modified to suit his customs. This point is of greater interest when one considers that in Dr Collignon's speculations he notes this peculiarity of the tibia, and thinks that it might be induced by a more habitual state of flexion of the limb, with which view I concur, and in consequence he supposes the gait of these people was less erect than that of their modern representatives. He then contrasts the tibiæ he describes with those of the gorilla. Here his suppositions are, I think, erroneous. The Panjabi is an example of a man with an upright gait, but with a tibia very materially curved backwards! It is wise to distrust opinions till proved by facts, and to avoid the common error of making the facts conform to preconceived hypotheses. This would be best done by avoiding hasty generalisations, and by careful observations, and the comparison of specimens with their modern analogues. Also, I am inclined to think that these observations on the Panjabi knee-joint upset the conclusions of M. Fraipont (quoted by Mr Arthur Thomson in his paper, *opus cit.*, vol. xxiii., 1889), founded on an examination of the tibiæ of the men of Spy, that in the erect position the men of Spy "appeared to have the tibia and femur inclined to one another at an angle not so marked as we have seen in anthropoids, but still sufficiently pronounced as to render the difference between Quaternary man and the modern European very characteristic." It is probable that had I had the opportunity of examining only the tibiæ and femora of Panjabis, I might have formed like con-

clusions with reference to them; but, having studied these people both when alive and when dissected, I understand how it is that the thigh and leg are not inclined to one another at an angle, though they may resemble Quaternary man as to their tibiæ. Such considerations are too often overlooked by observers in the study of human remains, and it is possible to reach the most opposite ideas from limited investigation or imperfect knowledge of the *reliques* and customs of tribes that might have precisely the same habits, which would account for similarity in osseous peculiarities.[1]

Quaternary man probably squatted and sat after the manner of Orientals, as opposed to Europeans.

I have noted that the trunk weight in the squatting posture is supported mostly by the heels and backs of the tibiæ. From the tibiæ the weight falls on the astragali—the necks of which have one, or may be two, extra facets, and the inner surfaces specially prolonged articular pyriform portions (figure 8), all of which are due to the excess of function in the joint owing to the position of extreme flexion in the ankle. From the astragali the weight is transmitted to the inferior calcaneo-scaphoid ligament, which thus bears a relatively greater strain than in the European, and, therefore, the tib. postici will have more to support, as also will these same muscles have greater work to perform when the individual rises from such a squatting posture. An excess in development will naturally be the result, and consequent alterations will occur in the muscular attachments to the tibiæ. The tibiæ should be flatter. The index of platyknemia amongst Panjabis is comparatively high—varies from 58·5 downwards,—the average of 52 tibiæ taken promiscuously being 69·9. Of the 52, forty-five possessed inferior anterior facets, and of these 55·5 per cent. showed distinct evidence of flattening, in some cases very pronounced. The remaining seven, on which the facets are absent, only show signs of flattening in 28·5 per cent., and when present it is but slight. There is thus a certain relation between the breadth of the

[1] M. Manouvrier, in an "Étude sur la Rétroversion de la tête du Tibia," in the *Mémoires de la Société d'Anthropologie de Paris*, 2e série, t. iv., 1890, has employed a similar line of argument to that in the paper. M. Manouvrier's observations were made chiefly on the tibiæ of Neolithic men, modern Parisians, and California Indians.—EDITOR.

tibia and the power of flexion at the ankle-joint. The tibia is flatter when the facets are present—though not always—that is, when most strain would be thrown on the calcaneo-scaphoid ligament. That the flattening was not due either to hill climbing, or acquired from indulgence in the chase, will be understood when it is known that these Panjabis were all dwellers on a plain (Panjab) as level as Holland, had most probably never revelled in the pursuit of "game" higher than that of a crow or sparrow, and their only "mountaineering" was within the limits of a glimpse of the Himalayan snows in the far horizon! The explanation of the occurrence of comparatively flat tibiæ amongst them must be sought not here. Will the strain thrown on the posterior tibial muscles by the squatting posture do so? If not, what will? May not the more frequent occurrence of platyknemia in ancient, savage, and Oriental races, and its diminution in frequency under the influence of civilisation, be due in a measure to the adoption of the chair to sit on amongst the civilised, in contradistinction to the squatting habits of the former. If so, the history of the influence of the chair upon the tibia has got to be written. Look at figure 1 and see the squatting posture. When it is borne in mind that a great portion of the individual's life is passed in this position —in which he works, eats, can sleep, and enjoy "sweet converse" with his friends in "the cool of the evening" all equally well—it cannot be doubted that changes in the bones, muscles, and joints will be found, in virtue of the physiological law that function makes the organ. Mr Arthur Thomson (page 627, vol. xxiii., *opus cit.*), in speaking of the external condyloid (tibial) convexity and the inferior anterior tibial facets, and the facets on the neck of the astragalus of the Neolithic skeleton in the Oxford Museum, says that in these respects it presents a marked contrast to the modern European type, and a close resemblance to the contemporaneous lower races. Most certainly; and doubtless the explanation is that our Neolithic ancestors did not enjoy the luxury of a chair any more than many of our fellow-subjects in India at the present day. Circumstances remaining similar, there is little variation; and so a close similitude in osteological configuration may be due to resemblance in habit and conditions of existence.

At the hip-joint a certain amount of abduction is combined with the extreme flexion, and the abdomen is received between the two thighs. The position is quite as easy to a Panjabi Falstaff as it is to an Oriental with the proportions of a Slender. This shows the extreme mobility of the hip-joint in these races. In the European it often happens that increasing corpulence deprives the individual of the power of tying his shoe latchet! not to mention that he would find it impossible to attempt the squatting posture! As the lower and inner lip of the acetabulum in the Panjabi is more developed (figure 3), safety from

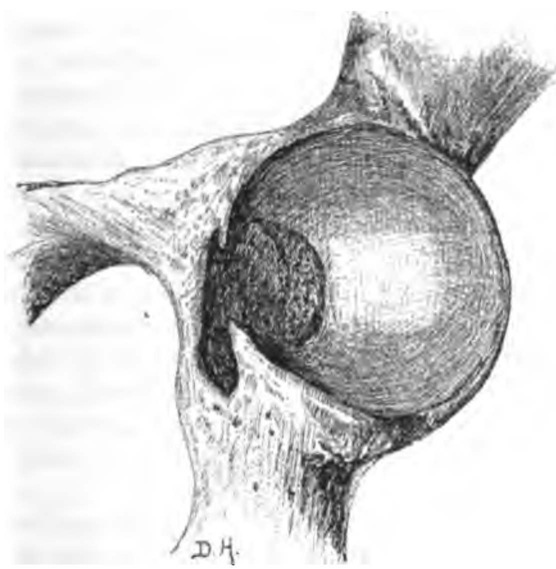


Fig. 3.

luxation is ensured. It is the vicarious use of the two positions, squatting and sartorial, that accounts for the modification in the ischial portion of the cotyloid cavity, the increased articular area on the head of the femur, and probably the somewhat elongated femoral neck, which an examination of a considerable number of specimens impresses on one as being typical of the Panjabi hip-joint.

I shall note now the chief anatomical points of comparison in the lower extremity.

The most distinctive differences between the morphology of the acetabulum of a native of the Panjab, and probably also of most Orientals who adopt the same habits of sitting and squatting, are to be found

*1st* and principally, in the great size of the ischial portion of the facies lunata. The rim of the acetabulum here is very prominent—the groove for the obturator externus below it being consequently deep (fig. 3).

*2nd*. In the extension forwards and widening out of the lower horn of the facies lunata, whereby the cotyloid notch is, as it were, partly bridged over, instead of being an irregular open space. It looks as if the transverse ligament were ossified on its ischial side.

*3rd*. The cotyloid notch, which in the European os innominatum is as a rule an open notch, presents in every well-marked Panjabi pelvis the characteristic, shown in fig. 3, of being partially arched over by the forward and upward prolongation of the inferior cornu of the facies lunata. The superficial boundary of the cotyloid notch in the European consists of the transverse ligament alone; the same boundary in the Panjabi consists of *bone* (portion of the ischium) plus the transverse ligament. The vessels entering the joint pass under the bony roof, and not under the ligamentous portion. The reason of this I will consider further on.

In the squatting posture (fig. 1) the upper and back part of the head of the femur rests against the ischial portion of the facies lunata—being supported by bone. Were an European able to flex the hip-joint to such an extent, and practise temporarily a like habit of squatting, the head of his femur would be supported partly against his transverse ligament, and the strain would be borne by the weakest part of the capsule, thus obviating luxation. In this posture in the Panjabi security is obtained by the femur resting on the enlarged inferior cornu, and the arthritic vessels are better protected—the spine of bone above and outside them guarding them.

A comparison of fig. 3 with the European pelvis will demonstrate clearly the differences I have noted.

The anatomical points in the upper end of the femur, due to increased mobility in the Oriental hip-joint, are, a larger articular area in proportion to the size of the head, and a well-marked neck, which allows by its length of a greater range of motion. Fig. 4 shows the upper end of a Panjabi femur. The view is from above, and, if compared with a European femur, á difference in the outline of the articular surfaces will be seen. In the European it is generally a line more or less straight. In the Panjabi, the outline, superiorly and anteriorly, is curved


Fig. 4.

where it joins the neck, and at the antero-superior border forms a well-marked convexity ($x$). Posteriorly, the convexity comes into apposition with the greatly-developed inferior cornu of the facies lunata of the acetabulum in the squatting posture. The groove for the obturator externus tendon on the posterior surface of the neck below the articular surface is always very well marked. This is not so frequently found in European specimens. The tuber colli inferior is also of considerable size, as the pubo-femoral ligament, in the majority of bodies, is found

to be a structure of very considerable strength, quite unlike "the prominent but weak internal accessory band" described by Prof. Macalister from dissections of European bodies.

The most noteworthy point in the modification of the articular surface of the femur at the knee, exemplifying a modification of structure due to function, is seen in the great prolongation of the internal condylar articular surface upwards to the origin of the gastrocnemius. Fig. 5 shows the posterior view of the lower extremity of a Panjabi femur. When the figure is compared with a European femur, it will be at once apparent, even

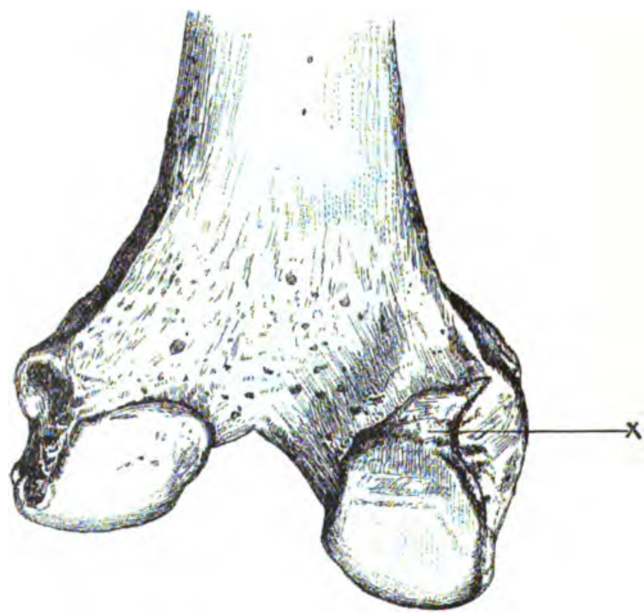


Fig. 5.

from a cursory glance, that the articular surface in the former case is much more largely developed. In the very extreme flexion of the knee which occurs in squatting, it is the surface in question that is in relation with the internal semilunar cartilage on the internal tuberosity of the tibia, which is, as I shall show, also developed more in a backward direction than is usually found in Europeans. Were it not for this mutual coaptation of parts the femur would have a tendency to slip

downwards and backwards from off the tibia. The femoral internal condyle of a Panjabi, therefore, has a *superior* surface ($x$) *which is articular.* (It presents—1. an articular facet ($x$); 2. origin of gastrocnemius.) The superior surface of the internal condyle of an European femur is *non*-articular, and is occupied by the origin of the gastrocnemius only.

The modifications of the superior surface of the external tuberosity of the tibia, so well shown by Mr Arthur Thomson, I have found to be exemplified in all the tibiæ in my collection. As to the true description of this surface, I agree with that anatomist in considering that, antero-posteriorly, flatness is the exception, and convexity the rule. The degree of convexity would be 2·5 to 3 of Thomson's scale. I may note, however, that this convexity of the external condylar surface is associated also with the backward curve of the upper extremity of the tibia. It is doubtful, therefore, whether a backwardly-curved tibia is compensatory to a flat external condylar surface. In some of my best-marked specimens the convexity of this surface is considerable, and it is associated with obliquity of the upper extremity of the tibia, a degree of platyknemia and well-marked inferior anterior facet. As far as I have observed, I have not noted that *flatness* of the condylar surface is associated with obliquity of the shaft. The great obliquity of the upper extremity of the tibia renders the internal tuberosity very prominent posteriorly. The upper surface of this tuberosity is also itself very slantingly placed. Figure 6 represents the inner surface of the head of a Panjabi tibia. When compared with a European, it will be noted that the tibial spine, with a portion of the articular surface, is quite visible in the former, whereas in the latter nothing is seen of either.

Extreme flexion of the knee, with full security from luxation, is facilitated by (1) the peculiarity of an articular facet on the *upper* surface of the femoral internal condyle; (2) the convexity of tibial external condylar surface with the prolongation of the same surface down posteriorly for tendon of popliteus and external semilunar cartilage (as shown by Mr Arthur Thomson); (3) obliquity of articular surface of internal tuberosity; (4) obliquity of upper extremity of tibia to its shaft; (5) a well-marked tubercle to the tibia, giving attachment to a *long* and strong lig. patellæ.

I introduce here the measurements of the diameters of 52 tibiæ, with the platyknemial index computed for each, as well as

D.H.

Fig. 6.

a column showing the presence or absence of the inferior facet. The measurements are after Broca's method. Facets will be seen to be present whether the platyknemia be high or low.

TABLE.

*Table of Measurements of 52 Tibiæ, showing Degrees of Flattening of Shaft when Anterior Inferior Facet is present or absent.*

| Serial No. | Diams. of Tibiæ. | | Index of Platyknemia. | Facet. | Serial No. | Diams. of Tibiæ. | | Index of Platyknemia. | Facet. |
|---|---|---|---|---|---|---|---|---|---|
| | Trans-verse. | Antero-Posterior. | | | | Trans-verse. | Antero-Posterior. | | |
| 1 | 20 | 30 | 66·6 | F. | 27 | 20 | 30 | 66·6 | F. |
| 2 | 25 | 34 | 73·5 | ... | 28 | 21 | 34 | 61·7 | ... |
| 3 | 21 | 30 | 70 | ... | 29 | 20 | 29 | 68·9 | F. |
| 4 | 22 | 32 | 68·7 | F. | 30 | 21 | 33 | 63·6 | F. |
| 5 | 21 | 31 | 67·7 | F. | 31 | 19 | 24 | 79·1 | ... |
| 6 | 26 | 34 | 76·4 | F. | 32 | 22 | 34 | 64·7 | F. |
| 7 | 19 | 24 | 79 | F. | 33 | 21 | 30 | 70 | F. |
| 8 | 20 | 34 | 58·8 | F. | 34 | 21 | 30 | 70 | ... |
| 9 | 24 | 37 | 64·8 | F. | 35 | 21 | 33 | 63·6 | F. |
| 10 | 21 | 31 | 67·7 | F. | 36 | 24 | 41 | 58·5 | F. |
| 11 | 20 | 29 | 68·9 | F. | 37 | 25 | 39 | 64·1 | F. |
| 12 | 27 | 40 | 67·5 | F. | 38 | 19 | 24 | 79·1 | ... |
| 13 | 27 | 37 | 72·9 | F. | 39 | 19 | 21 | 90·4 | F. |
| 14 | 25 | 35 | 71·4 | F. | 40 | 24 | 34 | 70·5 | F. |
| 15 | 25 | 34 | 73·5 | F. | 41 | 19 | 30 | 63·3 | F. |
| 16 | 25 | 36 | 69·4 | F. | 42 | 24 | 32 | 75 | F. |
| 17 | 22 | 29 | 75·8 | F. | 43 | 21 | 31 | 67·7 | ... |
| 18 | 20 | 30 | 66·6 | F. | 44 | 17 | 25 | 68 | F. |
| 19 | 24 | 34 | 70·6 | F. | 45 | 24 | 35 | 68·5 | F. |
| 20 | 19 | 24 | 79·1 | F. | 46 | 24 | 31 | 77·4 | F. |
| 21 | 16 | 25 | 64 | F. | 47 | 23 | 36 | 63·8 | F. |
| 22 | 23 | 34 | 67·6 | F. | 48 | 22 | 36 | 61·1 | F. |
| 23 | 27 | 34 | 79·4 | F. | 49 | 21 | 29 | 72·4 | F. |
| 24 | 24 | 35 | 68·5 | F. | 50 | 29 | 38 | 76·3 | F. |
| 25 | 29 | 39 | 74·3 | F. | 51 | 21 | 29 | 72·4 | F. |
| 26 | 21 | 29 | 72·4 | F. | 52 | 22 | 34 | 64·7 | F. |

**Average Index of Platyknemia of 52 Tibiæ = 69·9.**
**Facet present in 45.**
**,, absent in 7.**
**Amongst the former, 55·5 per cent. present evidences of flattening, and in some cases this is pronounced.**
**Amongst the latter, only 28·5 per cent. show signs of flattening, and even when present it is but slight.**

The changes brought about in the ankle-joint by peculiarities of posture are :—

1. Those on the inferior extremity of the tibia.
2. Those on the upper surface of the astragalus.
3. Those on the inner surface of the astragalus.

1. *Those on the Inferior Extremity of the Tibia.*—The facet mentioned by Mr Arthur Thomson in his valuable paper already

quoted, is generally present in 75 per cent. of those examined. In addition, there is frequently a second of a smaller size, occupying a more internal position (fig. 7). This facet, in addition to

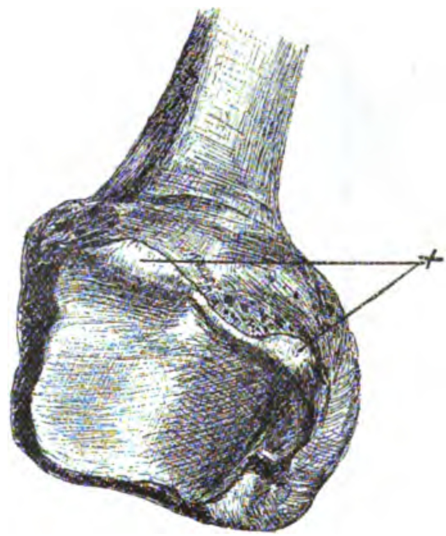

Fig. 7.

being smaller, is of a more elongated form than the external one. The same cause doubtless produces both.

| | | |
|---|---|---|
| Inferior Tibial Facets. Tibia examined = 52 | Outer and inner facets present | = 9 |
| | Outer alone present . | = 36 |
| | Inner alone present . | = 0 |
| | Both absent . . . | = 7 |

2. *Upper Surface of Astragalus.*—Very rarely does the appearance presented by the astragali figured in English text-books of anatomy hold good that the trochlear articular surface ends in front, bounded by a more or less definite transverse line, and presenting a rough neck anteriorly. In the majority of Panjabis will be observed a prolongation on the outer side (fig. 8), which encroaches on the upper surface of the neck, and which is received during extreme flexion into the larger (the external) of the two facets on the anterior margin of the lower extremity of the tibia.

To the inner side another facet, which is an anterior prolon-

gation of the trochlea, and is continuous internally with the pyriform malleolar facet (fig. 8) is frequently present.

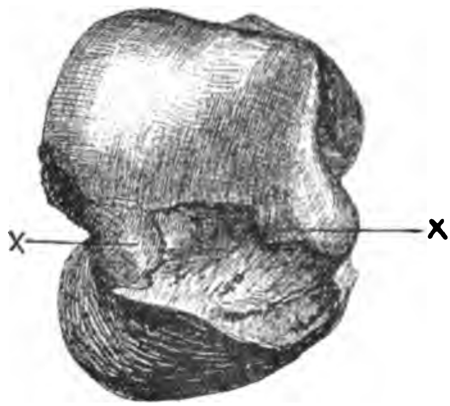


Fig. 8.

| | | |
|---|---|---|
| Facets on upper surface of neck of Astragalus = 53 Astragali. | Outer and inner facets present | = 18 |
| | Outer only present . | = 16 |
| | Inner only present . | = 7 |
| | Outer doubtful . | = 6 |
| | Both absent . . . | = 6 |

This is interesting when compared with Mr Thomson's criticism on Mr Shattock's conclusions (page 213, vol. xxiv., *Journal of Anatomy and Physiology*). Further on Mr Thomson states, with reference to the anthropoids:—"In some cases there was an extension forwards of the inner portion of the superior articular surface, but in no instance did this articulate with the facet on the anterior margin of the inferior articular surface of the tibia."

I have specimens which show the presence of an external facet (Mr Thomson's) on the neck of the astragalus for articulation with an external facet on the anterior surface of the lower extremity of the tibia (fibular side), as well as a prolongation of the trochlear surface forwards, which was received in articulation with the second facet to the inner part of the anterior surface of the lower extremity of the tibia.

There may be two facets on the anterior surface of the lower extremity of the tibia, and, corresponding to these, two facets on the upper surface of the neck of the astragalus. All these are much better seen in the recent specimens when coated with cartilage than on the dried and macerated bones.

3. *Inner Surface of Astragalus.*—The most striking difference here is the great prolongation anteriorly of the pyriform articular surface. In a well-marked bone it passes as far forwards as to occupy half the inner portion of the neck. It is concave from before back, and continuous with the internal of the two facets (when it is present) on the upper surface of the neck. Figure 8 illustrates this peculiarity. It is easy to understand how the position of extreme flexion of the ankle in squatting (fig. 1), or extreme adduction of the foot in the sartorial posture (fig. 2), will be facilitated by the presence of the modified articular surface in question. The neck of the astragalus is much shortened in comparison with European bones, and the outer margin is also thinner.

Before ending, I may note an observation as regards the facet or facets present on the upper surface of the os calcis for articulation with the head of the astragalus. Of a total of 57 bones, 34 had the facet double, the same as that figured on page 193 of Professor Macalister's *Text-Book of Human Anatomy*. In 23 bones the facet was single, similar to the figure on page 130 *Quain's Anatomy*, vol. ii. part 1, though most generally there was no indication whatever of any transverse line showing a tendency to subdivision.

## Resumé.

1. The acetabulum of the Panjabi presents certain points of contrast with that of an European.

2. The differences are most notable in the cotyloid notch and the shape and size of the inferior cornu of the facies lunata.

3. The articular surface of the head of the Panjabi femur is of greater extent relatively and absolutely than that of an European bone. The articular area on the former is specially prolonged to adapt itself to the modified facies lunata of the acetabulum during extreme flexion and partial abduction of

the hip-joint occurring in the squatting posture so commonly assumed by the native of India.

4. The neck of the femur in the Panjabi is longer relatively than in the European.

5. The *upper* surface of the internal condyle of the Panjabi femur is partly articular.

6. The articular surface mentioned in No. 5 is due to the power of extreme flexion possessed by the Panjabi knee-joint.

7. The head of the tibia in the Panjabi is set on the shaft very obliquely. A Panjabi tibia can be easily held by the finger and thumb when the internal tuberosity is grasped behind by them.

8. The upper surface of the internal tuberosity of the Panjabi tibia slopes considerably down and in—it is never flat.

9. The external tuberosity of the Panjabi tibia has its condylar surface convex from before backwards, and the articular area is prolonged down posteriorly.

10. The upper part of the tibial diaphysis in the Panjabi is commonly directed obliquely backwards.

11. Flattening of the tibial shaft is fairly common amongst natives of the Panjab.

12. The individuals whose tibiæ have been examined were neither hunters nor hill-men, but dwellers in the plains. Any degree of platyknemia present could not, therefore, be due to the generally assigned causes.

13. A facet upon the anterior surface of the inferior extremity was in the great majority of cases present.

14. This facet is for articulation with a like surface upon the neck of the astragalus.

15. The facets upon the anterior inferior surface of the tibia and on the neck of the astragalus come into apposition during extreme flexion of the ankle-joint in the squatting posture.

16. In upwards of 17 per cent. of the tibiæ examined a second facet, occupying a more internal position to that mentioned in No. 13, was present.

17. This facet articulates with an anterior prolongation of the trochlear surface of the astragalus upon the upper portion of the neck of that bone.

18. There may thus be two facets upon the anterior surface

of the lower extremity of the tibia. Of these the external is the commoner. The internal facet I have not found without the external being also present.

19. The Panjabi astragalus contrasted with the European differs considerably. There is a facet on the upper surface of the neck to the outside; there is a facet on the same surface more internally, which is continuous posteriorly with the trochlea and internally with the pyriform malleolar articular area. This pyriform articular area on the inner surface is greatly prolonged forwards, and, when so, it is concave from before backwards.

20. The outer facet alone may be present.

21. The inner facet alone may be present.

22. The greatly elongated pyriform facet on the internal surface may be the only distinctive character.

23. The sartorial position is rendered easier by the presence of this last-mentioned elongated articular area.

24. The foregoing peculiarities in the morphology of the hip-, knee- and ankle-joints of the Panjabi skeleton are owing to the influence of the squatting and sartorial postures which are commonly assumed by Orientals when engaged in their daily avocations or when indulging in rest after their labours.

25. The resemblances between the osteological remains of the lower extremities of prehistoric man and that of savage or Oriental races of the present day may be due to the influence of common habits.

26. It is highly probable that all the foregoing peculiarities are acquired; but that heredity has no influence has yet to be proven.

I have to thank my friend Dr W. P. Dickson, of the Central Jail, Lahore, for the great pains and trouble he has taken in photographing the specimens. The figures are in part from these photographs, and in part from sketches made by Dr David Hepburn from the photographs and from bones presented by the author to Sir William Turner.

# THE MAMMARY GLAND IN A GRAVID PORPOISE (*PHOCÆNA COMMUNIS*). By DAVID HEPBURN, M.D., F.R.S.E., *Senior Demonstrator of Anatomy, University of Edinburgh.*

IN the month of December 1892, Sir Wm. Turner procured an adult female porpoise, and, while it was being photographed prior to dissection, its contour led to the impression that the animal was gravid, which was confirmed when the abdomen was opened, for a fœtus 9¾ inches long was situated in the left uterine cornu. I made a careful examination of the mammary gland, and through the kindness of Sir Wm. Turner I am able to submit the following record of the investigation.

## I. *Dissection.*

On removing the skin and the subjacent layer of blubber from the abdominal wall, a stratum of muscle—the panniculus carnosus—was exposed. This layer consisted of aponeurotic and muscular fibres, the direction of the latter being from above (*i.e.*, the dorsum) downwards and backwards. They extended from the ventral mesial line to the external or upper border of the mamma, where an aponeurosis replaced the muscular tissue. Having raised the panniculus carnosus, the mamma was completely exposed. It lay upon the outer surface of the muscles forming the antero-lateral wall of the abdomen.

In general form, the gland was an elongated flattened organ, shaped somewhat like a large pancreas. Its anterior end was almost on a level with the umbilicus, and from this point the gland extended backwards until it came opposite the aperture of the vulva. Its greatest length was 13 inches, and its greatest breadth 3 inches, but at each end it gradually narrowed to about half that breadth. The lower border was situated close to the ventral mesial line. The greatest thickness of the gland was an inch and a half. At its posterior end the gland communicated with a saccule or reservoir full of milk, 2 inches in length, and capable of containing about 2 ounces of fluid. Th

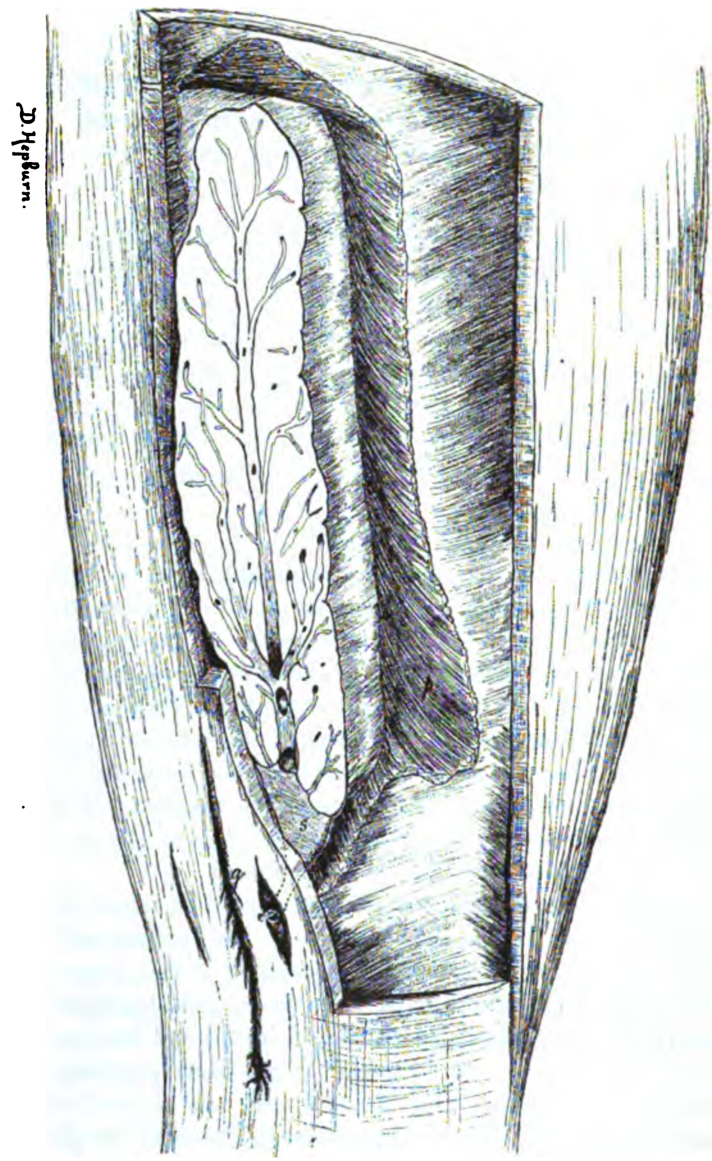


FIG. 1.—Semidiagrammatic view of a longitudinal section of the mammary gland *in situ*. The gland is dissected to show the branching duct. *S*, the milk sac; *p*, the panniculus carnosus; *g*, the genital slit.

saccule continued the long axis of the gland, and opened externally through a single nipple.

The nipple did not form a projection on the surface of the body, but was entirely concealed from view within a narrow longitudinal slit-like fissure, from the bottom of which it rose. This mammary fissure measured 1 inch in length, and was situated parallel to and 1 inch distant from the lateral margin of the vulva, as well as 3 inches anterior to the anus. In its retracted state the nipple was scarcely a quarter of an inch in diameter.

By pressure on the surface of the gland, a thick, yellowish-white creamy milk readily exuded, while, at the same time, the nipple was slightly protruded through the fissure, and the milk was seen to escape from one orifice in its centre.

The surfaces of the gland were flattened, but shallow grooves containing blood-vessels formed a network over the surface. The borders were rounded and presented considerable irregularity, due to shallow notches which corresponded with the grooves on the flat surfaces.

A longitudinal transverse section through the entire length of the gland revealed the fact that the saccule communicated with a duct as large as a human femoral artery, and the duct maintained this calibre for a distance of an inch and a half into the substance of the gland. The mouths of seven or eight tributaries opened into this large duct, while two or three ducts of medium size opened directly into the saccule. The mouths of all these ducts (with the exception of the main duct) opened obliquely, and each was provided with a semilunar fold or reduplication of the lining membrane, which acted as a valve to partially close its orifice when pressure was applied to the mouth of the duct. The terminal tributary of the main duct was continued to the extreme end of the gland, in the substance of which it occupied a position nearer to the mesial than to the outer border and close to the superficial surface. The saccule presented a single chamber, into which all the ducts already specified opened, while it discharged its contents through the nipple by a single canal, which freely admitted an ordinary dissecting-room blow-pipe. The wall of the saccule consisted of a thin layer of fibrous tissue, continuous with the general invest-

ment of the gland substance. According to Owen,[1] "the nipple itself is perforated by numerous lacteal ducts;" but in the present specimen, the naked eye did not reveal other than the one central canal, of the calibre already mentioned.

## II. *Microscopic Examination.*

Portions of the gland were prepared for the microscope by hardening them in an aqueous solution of corrosive sublimate, embedding in paraffin, and cutting in the usual way. Three different reagents were used in the staining of each section, for the purpose of readily discriminating between the fibrous, cellular, and vascular constituents of the gland. From the deep surface of the fibrous capsule which enveloped the entire gland, prolongations passed inwards, dividing the gland substance into numerous lobules. These were very closely packed together, and there was no trace of fat deposited around them. Each lobule consisted of clusters of alveoli, supported by finer ramifications of the fibrous trabeculæ, in which there were the ramifications of a network of blood capillaries.

Each alveolus was surrounded by a *membrana propria* or basement membrane, which reacted to the staining agent in the same way as the fibrous reticulum, and at intervals presented flattened nuclei. Internal to the basement membrane, the alveolus was lined by the secreting epithelium, and, according to the line of section, so the alveoli appeared more or less full. The shape of the individual secreting cells was much modified in accordance with surrounding pressure, but in general it presented a cubical appearance. Each cell possessed a large well-marked nucleus, most frequently situated in close proximity to the basement membrane. Many of the nuclei showed several nucleoli, and in some places two nuclei were visible in one cell. Clear spaces or lacunæ were present in most of the secreting cells towards their free ends, which were frequently ragged as if portions had broken off. Granular debris and rounded nucleated cells occupied the cavity of the alveolus. The contents of the alveolus made their exit by a

[1] Owen, *Anatomy of Vertebrates*, vol. iii. p. 777.

small duct, whose lumen was much narrower than the diameter of the alveolus. This duct opened into one of larger size, and so on until the main channels were reached. These galactophorous ducts were lined by a layer of flattened epithelial cells. Their walls consisted of fibrous tissue, and scattered amongst the fibrous tissue there were cells possessing elongated nuclei, which probably belonged to non-striped muscular fibres. The contents of these ducts were similar to those of the alveoli, and in addition, fat cells were readily distinguishable. It was easy to discriminate between small milk-ducts and blood-vessels of


FIG. 2.—Transverse section of the gland-substance showing two alveoli (AA), with their contained cells, a small blood-vessel (V), and a small galactophorous duct (D).

a similar size by reason of their respective contents, as well as by the presence of the elastic lamina characteristic of an arterial wall.

From what has been said, it is quite evident that the gland under consideration belongs to the compound racemose or acinous type. When compared with the human mamma, the appearances presented by the mamma of the Porpoise closely correspond to a very much enlarged view of a single *lobe* of the former, in which the *ampulla*, with its *single lactiferous duct*, correspond respectively to the saccule or reservoir and the

single canal passing through the nipple of the Porpoise, while the glandular lobes in each only differ in respect of magnitude and in the absence of a surrounding deposit of adipose tissue, from the mammary lobules of the Porpoise. In a detailed account of the mammary gland in a Great Finner Whale (*Balænoptera Sibbaldii*), which was gravid, Sir Wm. Turner[1] has described a gland which, in its position and in the arrangement of its duct and nipple, was practically identical with that of the Porpoise; a point of difference being, that in the former a portion of the gland substance extended "behind the nipple." It would appear, therefore, that this particular form of mammary gland is characteristic of the Cetacea.

[1] W. Turner, "An Account of the Great Finner Whale (*Balænoptera Sibbaldii*) stranded at Longniddry," Part I., *Trans. Roy. Soc. Edin.*, vol. xxvi.

# ON SOME CONDITIONS RELATED TO DOUBLE MONSTROSITY. By BERTRAM C. A. WINDLE, D.Sc., M.D., M.A., *Professor of Anatomy in Mason College, Birmingham.*

IN a former paper published in this *Journal*, in which the main subject of double monstrosity was dealt with, I was obliged to defer the consideration of certain interesting conditions nearly related to that teratological category. The conditions mentioned were those of parasitism, and of unilateral hypertrophy of the body or of a part. In the present paper I do not propose to say much about the condition of true parasitism: the condition, that is, in which some structure or structures are appended to some part of the autosite, which may, for the present at least, be considered as representing the atrophied body of a second fœtus. My object has been, firstly, to bring together some instances of minor duplicity of considerable interest on their own account; and secondly, to discuss the relationship of these cases, and of the condition of partial hypertrophy, to that of fully developed double monstrosity.

## SECTION I. MINOR FORMS OF DUPLICITY.

The cases which are here included are those in which one member or part, or but little more, is attached to some portion of the body of the autosite (to employ this term for the present), in addition to the normal member or part. Such additional parts may be subdivided into (1) homotopic redundancies, *i.e.*, cases where the supplemental part is placed close to the normal one; and (2) heterotopic redundancies, *i.e.*, cases where the supplementary part is placed at some part of the body remote from that occupied by the normal representative. An additional stage in classification might be reached by again subdividing each of these classes into axial and peripheral, according to whether the trunk or limbs form the site of implantation of the abnormal part. I shall now proceed to consider some cases

falling under these categories, before passing to the general subject of their causation and connections.

### *Homotopic Redundancy.*

1. *Dignathia.*—Duplicity of the maxillae may exist under several forms, as will be seen from the cases subjoined. In the first group the additional member or members are contained within the arch of the normal. Cases.—(*a*) This case was observed by myself, and is represented in figs. 1 and 2.[1] The fœtus was sent to me on account of the abnormal condition of the genitalia, which were apparently those of a female, but without any clitoris. Dissection, however, revealed the presence of a testicle in either half of what was the divided scrotum. There were additional digits on each of the extremities as follows:—Right hand, a small additional minimus; left hand, do., but rather larger; left foot, bifid hallux, with two well-formed nails, also an additional minimus implanted on the dorsum of the normal digit; right foot, a similar condition, but the nails of the halluces were fused and the additional minimus was smaller. The most remarkable points were those connected with the bones of the head. The inferior maxilla was double,

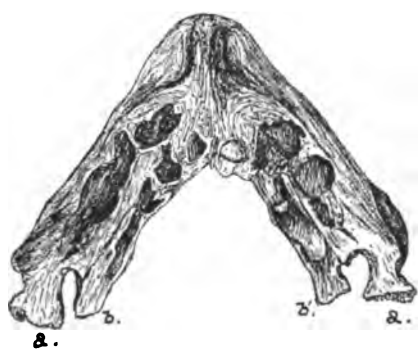


FIG. 1.—Inferior Maxillæ from case of Dignathism. *a,a*, normal and outer jaw; *b,b*, superfluous inner jaw.

one being placed within the arch of the other, to which it was firmly and continuously attached. The line where union had

[1] I have to thank Mr A. P. Maddocks for these figures, and Mr A. Watson for fig. 3.

taken place was distinct above, and still more clearly so below. The fusion at the symphysis was so complete that no line could there be seen. The inner and smaller jaw had diminutive condyles and coronoid processes, the latter fusing on each side


FIG. 2.—Superior Maxillæ from case of Dignathism. *a*, remains of supernumerary right maxilla, containing a tooth-germ; *b*, remains of supernumerary left maxilla.

with the edges of the lingulæ of the outer jaw. The central teeth at the symphysis might have belonged to either jaw, but behind them there were, as the figure shows, two parallel rows of alveoli on either side, each containing well-formed tooth-germs. There was thus present almost complete duplicity of the lower jaw. On the under surface of the palate were traces of duplicity of the upper jaw. On the right side there was a shell of bone, 10 × 6 mm. in size, which was attached by mucous membrane to the superior maxilla between the alveoli for the molars and those for the incisors, and in part in the position of that of the canine, which was not visible. This shell of bone contained in its interior a distinct tooth-germ, calcified, on which account I take it to represent one side of the superior jaw arch belonging to the superfluous maxilla. The other side was represented, as I read the case, by a linear strip of bone attached by mucous membrane to the inner border of the molar alveoli of the left side. This slip of bone was unprovided with any representatives of the teeth. (*b*) Seiler (1), supernumerary jaw attached inside the normal one to the lingula, and at the symphysis with rudimentary coronoid and condylar processes. (*c*) Lannelonge (2), cleft in lower lip and between halves of the mandible, in the aperture

between which was a tumour, which on examination proved to be a rudimentary lower jaw with teeth-germs. (*d*) St Hilaire (3), a case very similar to (*a*), occurring in a calf. Placed by the author in a separate class, called Augnathus. (*e*) Dana (4), a piece of bone attached to a cartilage at the mandibular symphysis in front, and articulating with the palate behind, which caused bifidity of the tongue; seems to be a minor form of this class. The next group consists of cases in which the jaws are placed side by side. The following are instances. (*f*) Taruffi (5), a sirenomelic fœtus in which two pairs of jaws were placed side by side, each pair containing one-half of the bifid tongue. The mesial condyles articulated with an accessory bone, arcuate in shape, which was attached to the palate, contained tooth-germs, and evidently represented supernumerary superior maxillæ. (*g*) St Bartholomew's Hospital (6), anencephalous, the outer condyles of the lower jaws are normally articulated; their median or inner condyles, closely approximated, are articulated with a mass of bone projecting between and from the fronts of the divisions of the hard palate; bifid tongue. (*h*) Mayer (7), an irregular second mandible on one side of a normal one. (*j*) Israel (8), additional left half of lower jaw placed externally to the normal member. The two last cases may be looked upon as minor instances of the group under consideration. In the third group the additional jaw is placed under one ear, and has often a small accessory mouth connected with it. Instances are—(*k*) Rósciszweski (9): this case was met with, as are nearly all of this group, in a sheep. (*l*) Gurlt (10) states that a rudimentary lower jaw may be found under one or both ears (Dignathus or Trignathus), with incisor teeth, a small mouth and tongue. He knew of no human case, nor have I found any. Amongst animals, especially sheep, the condition is not rare. (*m*) Schultz (11), a similar condition in a calf.

In the last curious group (Hypognathus Antistrophus of Taruffi) the additional jaw is attached in front of the symphysis of the normal member, projects in the opposite direction, *i.e.* away from the mouth, and is upside down; (*n*) Taruffi (12); (*o*) Lesbre (13).

Without dealing fully with the nature of these malformations at present, it may here be mentioned that St Hilaire placed

them in a special group, which he included in the general class of Epignathus, one of the recognised forms of parasitism. No hard and fast line can be drawn between major forms of Dignathus and minor forms of Epignathus, as is well shown by an interesting case of Sutton's (14), which, while epignathous, has many features similar to those of the group under consideration. In this case a tumour was found wedged in between the superior maxillæ in the head of a foal. The tumour consisted of a supernumerary upper maxilla, two rudimentary mandibles, and an extra tongue attached to the under surface of the basisphenoid. The interior of the cranium showed duplicity of the pituitary body, sella turcica, crista galli, and cribriform plates.

2. *Duplicity of the Nose.*—In this I do not include cases where the nose is divided, but consists still of two nostrils, as that condition is one of subdivision but not of superfluity. But in a case which I described some years ago (15), the nose was grooved down the middle line, and there were four nostrils, two mesial and blind and two lateral and functional. There were also two frænula to the upper lip.

3. *Polyotia.*—Otto (16) describes a calf with three ears.

4. *Diphallus.*—Förster (17) mentions a case in which there were two penes, one placed above the other. Urine was passed by both and semen by one.

5. *Diglossus.*—If the doubtful cases mentioned by Meckel (18) are to be considered veracious, they would be instances of true duplicity of the tongue, since one organ was placed above the other, the condition thus being different from that of bifidity.

5. *Multiplicity of Parts in the Limbs.*—The condition of redundancy in the limbs commences with the minor forms of polydactyly, and passes through a regular series of gradations to duplicity of the limb itself, and even in part of its girdle, without duplicity of the axis. In the anterior extremities, omitting cases of polydactyly, the first degree of division is that which has recently been carefully described by Jolly (19) and Dwight (20), in which the ulnar halves of two forearms and hands are fused to form one forearm, duplicity also existing of the lower end of the humerus. The sparse literature of the

subject being fully dealt with in the last-mentioned paper, need not be more fully referred to here. Instances of more complete duplicity of the upper extremity in the human species are given in the works of the older writers, such as Aldrovandus, Licosthenes, Licetus, and Schenk, but such a condition must at present be looked upon as unauthenticated, though not impossible. A greater amount of duplicity is not, however, uncommon in the lower animals. Thus, Guinard (13, p. 361) describes a case of a goat in which the scapula of the right side, besides its normal parts and appended extremity, possessed also two additional acromia, each with an upper extremity attached to the glenoid cavity, which it overhung. He gives also a figure from a memoir by Blanc of a sheep in which the normal and supernumerary fore-limbs were enclosed in separate sheaths of skin, but in which the condition of the bones, muscles, ligaments, and blood-vessels showed that duplicity of the limb, and not parasitism, was the explanation of the case. A condition closely resembling the above has been observed in the bird (21, No. 48), and in the frog by Bassi (22) and Sutton (23), and there is a specimen in the same amphibian in the College of Surgeons' Museum (21, No. 23).

In the posterior extremities, again omitting cases of polydactyly, mention may first be made of a case described by Brudi (24), in which, on the great toe of the left foot, in the angle between the inner and posterior borders of the nail, there was found a tumour of the size of a thumb-nail, attached by a short, thick, scarcely movable pedicle. At the peripheral end an articulation was distinctly recognisable, and on close examination the tumour was found to be a perfect, but exceedingly diminutive right foot. It possessed five toes, each with a nail, the fourth and fifth being united. The length from the base of the pedicle to the apex of the great toe was 17 mm. This may be looked on as a case of double foot, in which one member was much reduced in size. A far more advanced stage of duplicity is reached in the case of a monkey in the College of Surgeons, in which (21, No. 307) there is doubling of the whole inner side of the left limb. The obturator foramen was also double, and there were two tubera ischii. The still more complete con-

dition in which one or both of the lower limbs is doubled, with a greater or less amount of duplicity of the pelvis and external genitalia, has been carefully described in the human species, and dealt with by Cleland in connection with cases occurring with considerable frequency in birds (25). The most remarkable case known to me is that described by Wells (26), and alluded to in my former paper. The cases where the additional pelvic limb or limbs are connected with a tumour of the sacrum belong to the condition of parasitism, and several have been fully described by Braune in his monograph (27).

To the list of homotopic redundancies might be added cases of additional ovaries, testicles, and those serial redundancies which occur in the classes of vertebræ, ribs, and in some of the case of polymastia.

*Heterotopic Redundancy.*—Cases belonging to this class are, as indeed might be expected, much rarer than those of the first group, and I will now give a few instances of the more remarkable.

1. *Additional Genitalia.*—A remarkable case of this kind is represented in fig. 3, for which and for an account of the case I am indebted to the President of our College, Mr Oliver Pemberton, in whose practice it occurred. He was consulted by the young man by whom they were possessed, with regard to the propriety of his marrying. As he was provided with a fully-developed and functional set of genitalia in the normal position, in addition to those shortly to be described, permission was given to him: he married, and the case has been no more heard of. A water-colour sketch was made at the time, from which the figure has been reproduced. Over the lumbar vertebræ and on their posterior aspect was a slight elevation, similar to the Mons Jovis in front, which elevation was provided with hairs like those of the pubic region. From it there projected a second but imperforate penis, with a well-marked glans. There was a corrugated portion of skin near it, like a shrunken scrotum, but it contained no testes. This penis was capable of erection. The following cases are the only ones at all similar with which I am acquainted. Tsortis (28) observed the following condition in a soldier aged 21. On an elevation situated below the left

scapula, were placed an almost complete set of female external genitalia, lying with their long axis perpendicular, and 2·5 cm. in length. The labia externa, which were slightly open, were covered on their outer sides with black hairs. They united above into a kind of Mons Veneris. There was a small cavity between the labia, resembling a rudimentary vagina, above which was a small tubercle, like a clitoris. There were no labia minora. Maclaren (29) describes a case of a sireniform fœtus with reversed limbs as usual, on the anterior aspect of whose abdomen, and two inches below the umbilicus in the middle line, was a small papular nodule of skin without any opening. This papule would be looked upon, in an ordinary case of siren-omelia, as representing the deficient or only partially represented external genitalia commonly met with in this form, and probably should be considered in this light in the case in ques-

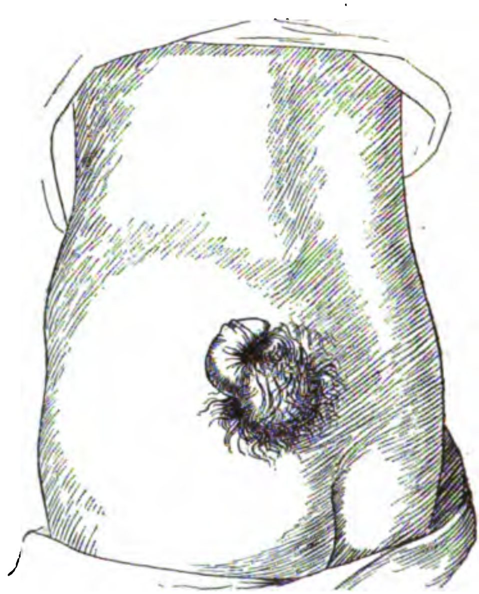

FIG. 3.—Supernumerary set of External Genitalia on Lumbar Region of Male.

tion. At a corresponding point to the papule, but posteriorly, hung, like a caudal appendage, a well-formed penis, with a pervious canal, but without any trace of scrotum or anus. This

case is not so complete as that first described, but is worthy of mention in connection with it.

2. *Additional Limbs not connected with the Girdles.*—The most remarkable instances in this class are those of a limb connected with the head, which have been observed in the duck alone, so far as I am aware, by St Hilaire (3, vol. iii. p. 272), Tiedmann (30), Meckel (31), and Gurlt (32), and of which a specimen is in the College of Surgeons' Museum (21, No. 47). The case described by Otto (16, p. 249), in a lamb being attached to a tumour, may be parasitic in its nature.

I omit particular mention of cases of noto-, pygo-, thoraco-, and gastro-melus, since a consideration of their nature would occupy too much space without corresponding advantage. One curious case described by Otto should, however, be alluded to. It consisted of a finger, composed of three phalanges with a nail, which was attached to a rounded fatty tumour placed near the anus, and on the coccyx. When removed, a passage directed towards the rectum was found beneath it, for which reason Leuckart (33) looks upon it as being a case of pygo-melus, an explanation which, if it involves the conception of parasitism as generally understood, is scarcely, I think, to be entertained.

3. *Teeth unconnected with the Maxillæ.*—Guinard (13, p. 187) states that Goubaux has found in the cranial cavity of a horse, killed at Alfort, a molar tooth, and that the same author has described a group of molar teeth met with on the base of the petrous portion of the temporal bone, also in a horse.

4. *Polymastia* (certain cases of).—It is possible that some of the cases of mammæ erraticæ described by various authors, and fully dealt with by Williams (34), may belong to the class of heterotopic redundancy, though, in view of the opinions expressed by the author just mentioned, their nature is exceedingly doubtful.

Having thus briefly glanced at the various forms of duplicity approaching the condition of double monstrosity, it will be interesting to discuss their connection with that condition in nature, origin, and development; but before making any remarks of my own, I propose to examine and classify the opinions on the subject of the more important teratological writers.

## SECTION II. SOME EXPLANATIONS OF THE MINOR FORMS OF DUPLICITY.

St Hilaire assumes the existence of a second fœtus, even in such slight manifestations of duplicity as dignathia. Describing his class of augnathus, he states that a modified inferior maxilla remains the sole and only vestige of the accessory individual. A similar, but more tentatively expressed, opinion is put forward in the College of Surgeons' Catalogue to account for the cases of cephalomelus and accessory wing above alluded to. Of the latter it is said:—"In the complete absence of any other means of accounting for the condition, it has been placed in this series (that of heterologous union), as it seems probable that the limb may be the remains of a second embryo." Panum (35) distinguishes between different groups: thus he considers that in all such cases as those of double limbs we have to do with true double malformations, in which originally a completely or partially double axial anlage[1] is present, one-half of which has become atrophied in the course of development. On the other hand, he compares the normal formation of digits to that process of budding by which many glands attain their normal development, and considers that some minor forms of duplicity may arise in a similar manner. Finally, in cases of a heterotopic nature, he cites with approval the opinion of Krabbe (36), who explains the so-called wandering teeth by supposing that a portion of the cells from which molars normally develop becomes detached, and connected with another visceral cleft. Panum thinks that transplantation of a special portion of tissue during fœtal life may also explain cases of dermoid cysts, containing ovary, testicle, or teeth, as well as some of the instances of so-called fœtus in fœtu. Förster also distinguishes in a somewhat different manner. Besides the doubling of the germ-anlage, he says, by which two limbs or organs lying near one another are produced, there is also a supernumerary formation of single parts,

[1] In his note to the translation of Weismann's *Germ-plasm*, Professor Parker alludes to the difficulty of finding an adequate equivalent for this word. I have ventured to follow the example of Minot, who, in his recently published *Human Embryology*, uses it as a specific term, without attempt at translation.

which cannot be explained in this manner, since the supernumerary part is not near the normal one, but is separated from it, and must have been formed from a special germ-anlage. Ahlfeld (37), whilst adhering in general to the fission theory, attributes fœtal transplantation (in this connection he is more particularly alluding to epignathus, sacral and other teratomata) to the grafting of cell-masses from the anlage of a rudimentary fœtus on the surface of a normally developing embryo. Doenitz (38) thinks that monsters with superfluity of single extremities should not be reckoned as double monsters. The cause of these is a division of the germ—a process of division in the material normally forming one organism. Cleland (25) says:—"There can be nothing more certain than that the mass of corpuscles, destined normally to form a single embryo, may, under some abnormal influence, break up into two, each of which inherits all the potentialities of the undivided mass, just as unicellular organisms produced by fission inherit the properties of the parent." This fission may be complete or incomplete, and he comes to the conclusion that "every vertebrate animal has at an early period of its existence a latent capability of splitting up indefinitely." Again, he states that "in the fission, which results in twins or double monstrosity, it is a numerous host of corpuscles which divides, and it is quite impossible to imagine that the members of this host shift their places from one part of the mass to another. It follows that individual corpuscles or groups of corpuscles become, after fission of the mass, ancestors of the textural elements of totally different parts of the body from those which they would have had to do with had the stimulus to fission not been given. It clearly follows that the power by which the different parts and organs of the organism are determined is not resident in the individual corpuscles." It will be seen that this theory places the period of the fission, which leads to double monstrosity, at a later date than that which I consider should be assigned to it. Sutton (14), speaking of the tumour in the pig which I have already quoted, says that the condition "cannot fail to suggest that such tumours, occurring in otherwise normally formed mammals, are slight manifestations of a process which finds its maximum expression in some forms of duplex monsters." And again (23):

—"The same tendency which produces dichotomy of the ray in star-fish, or digits in mammals, will, when it involves the axis of the limb, produce a supernumerary arm, wing, or leg; should it affect the axis of the embryo, will lead to the production of duplex monsters of varying development and different degrees of union, or even result in viable twins." This statement, so far as it goes, concisely states the view which I hold on this subject.

It has already been mentioned that Panum speaks of budding as an explanation of some of the forms of minor duplicity, and this view has also been put forward by other writers, such as Schutz (11), Taruffi, who speaks of "exaggerated gemmation," and Lereboullet, who distinguishes between division and the budding, which he considers to be due to a superfluity of embryonic material. Finally, it may be mentioned that Róscisz-weski (9) explains his case of dignathia by a process analogous to that called antholysis by botanists, for which he uses the term morpholysis.

## SECTION III. CONSIDERATION OF THE NATURE OF MINOR DUPLICITY.

The foregoing account of the opinions of different writers as to the nature of these minor forms of duplicity shows two distinct schools of thought. By the first, such superfluous parts, however small, are considered as being the remains of a second fœtus, the rest of which has atrophied in the process of growth. By the second, such an explanation is not considered necessary, but the condition is explained by fission or gemmation of the formative material normally belonging to one embryo. As to the cause of this division various explanations have been put forward, over which delay need not now be made. I have already given my reasons for believing that an excess of germ-plasm existing by some means in the oosperm is the cause of double monstrosity, and I think there is every reason for holding that similar but slighter excesses produce all the various forms of duplicity, from the full condition to the slightest manifestations. That no explanation of duplicity is satisfactory which does not embrace all its phases, and explain all alike, was pointed out

by Vrolik, who at the same time showed that this statement was one amongst many arguments against the fusion theory, in which that explanation which postulates a second fœtus to explain minor duplicity has its origin. No one would consider it necessary to postulate a second fœtus in order to explain an additional digit, a double hand, or a partly double limb, yet there is no gap in reality between these conditions and those where the former existence of a second fœtus has been assumed, which would enable us to believe that the two groups might have different explanations. In a superfluity of the germ-plasm we have, I think, an adequate explanation, indeed the only explanation, of all the forms of duplicity, the amount of excess of the former corresponding with the extent of superfluity shown by the latter. I have alluded in my former paper to the remarkable experiments of Roux, in which he showed, by destruction of one or more of the early segmentation-spheres in the ovum of the frog, that the first line of fission separates from one another cells which have different morphological values, since one forms the right, the other the left side of the body, or the one the head, the other the tail end, as the case may be. This view he logically advances further to the statement that each division cuts off cells, each of which contains the potentialities of forming fewer and fewer parts. In other words, with division occurs specialisation of cells. Thus the aggregate of cells forms a kind of mosaic-work, in which each cell contains the factors for the development of a certain part or parts, and for no other. In the recently translated work by Weismann (39), this theory has been further worked out; and it will be convenient to allude to that portion of his terminology which I shall use in the remainder of this paper. Those cells or groups of cells which are independently variable from the germ on he calls determinates, and those particles of germ-plasm corresponding to and determining them he styles determinants. Thus the theory put forward by His (40), that each point in the embryonic area must correspond to a later organ or part of an organ, is confirmed and rendered even sharper by Roux's experiments; and the particles of germ-plasm which control the development of each of these organ-producing areæ or cells are Weismann's determinants. Whether further knowledge will confirm all the theories contained in the

book in question or not, it may at least be said that the theory that each cell has its own special potentialities of development, and no others, and that these potentialities are contained in the particles of germ-plasm now described as determinants, is one which appears, on the evidence at present available, to be well established. It is certainly that which most satisfactorily explains the conditions with which I am at present concerned; indeed, as I shall endeavour to show, it is difficult to see how some of the conditions are to be accounted for on any very widely differing hypothesis. The views which I am now endeavouring to explain were formed from a consideration of the experiments of Pfluger, Roux, and others, in their bearing upon teratological problems; but I am glad to be able to adopt Weismann's terminology, which clearly expresses my meaning, and has besides much greater weight than any which I could devise would possess. The various forms of duplicity may, then, be explained by the existence in the germ of a more or less completely double set of determinants, or factors of development. If completely double, homologous twins or double monsters by adhesion are the result. If incompletely double, then there is produced a less perfect form of double monstrosity. In the case, for example, of the female described by Wells, where there were four lower extremities and two sets of genitalia, a double set of determinants for these parts of the body, and a single set for the remainder, must have existed in the germ. The nature of the so-called parasites is not so clear, since in some at least of these the factor of degeneration has to be taken into account. In the case, for example, of epignathus, Ahlfeld (41) states it as his opinion that those tumours which hang out of the mouth of a new-born child, so long as they are not cerebral herniæ, must spring from a second fœtus, even if no parts are found in them which can with accuracy be assigned to such a fœtus. He also holds that an embryonic anlage can so far degenerate as to produce such forms as are found in these cases and in sacral tumours. Whilst admitting that this explanation may be correct in such cases, I am doubtful whether it is correct to assume that in all of them, perhaps in many of them, the determinants of a second fœtus were all in existence at any time. Further evidence is required before a definite answer can be given to this question. A

similar statement must be made with respect to the acephali. Cleland has stated that "by far the most probable hypothesis to account for the production of completely separated acephali, is that they have become, in process of early growth, detached by fissiparous division from the completely developed fœtus which always accompanies such a monstrosity. An early rupture of this connection with the head and with the body of the perfect fœtus, in the case of a completely separated acephalus, would give freedom for growth of the part represented. That it is difficult, no doubt, to get a full proof of this theory may be frankly admitted. At the same time, it may happen any day that an opportunity may occur of examining the body of a healthy twin, born along with an acephalus; and it is possible that, in its internal structure, traces may be found of organs, *e.g.* lungs, originally belonging to the acephalus." By the kindness of my pupil Mr H. E. Darlington, I have had the opportunity of examining a case of this kind. The acephalus was of the usual œdematous type, and presented no characters differentiating it from many similar monsters, descriptions of which are upon record. I dissected with care the normal twin born with it, but without finding in it any traces of duplicity, or indeed of any deviation from the normal type. This, of course, does not prove that no such duplicity ever existed, since it is quite possible, having regard to the early period at which separation probably takes place, that such superfluous parts, if they existed, might have disappeared. But, whilst accepting Cleland's explanation of acephali as the most probable in the light of our present knowledge, I feel very doubtful whether the determinants of the missing parts of the body ever existed, and the case which I have described, so far as it goes, at least points in the direction of their non-existence. Passing from these forms to those with which I have dealt in this paper, I should explain the minor forms of duplicity by supposing that a second set of determinants existed in the germ for these parts, and for them alone. In thus speaking, I am not arguing against Sutton's view that these forms are due to dichotomy, but I think that dichotomy alone is insufficient to explain them. Dichotomy can explain such cases as those where the epiglottis or tongue, for example, are cleft into two equal parts, which together would

make up one normal organ. But dichotomy, without something further, such as an excess of germ-plasm, does not seem to me to be a sufficient explanation where there is superfluity as well as subdivision. This view, which I have held for some time, is also supported by the authority of Weismann. He says (p. 428), "I think it is highly probable that many congenital deformities, such as the occasional doubling of the tarsus in the hind-limbs of beetles and other insects, are due to the doubling of a group of determinants, and perhaps the much discussed and debated problem concerning supernumerary fingers and toes in human beings may be explained in a similar way." In the ordinary cases of duplicity, these determinants follow in the same track as their normal fellows, and having arrived at their destination, eventuate in the formation of an additional member or part. "As the individual determinants from the germ-plasm, onwards throughout all the stages of ontogeny, take up a definite position in the id, they must reach the right place in the body, and there cause the development of a structure corresponding to that of the part." And in a similar manner, the extra determinants, following the same track, produce the conditions of homotopic redundancy. In cases of heterotopic redundancy, which for this very reason would be much more rare than the others,[1] the determinants, for some reason, take an abnormal track, and proceed to development, in some position distant from that of their normal fellows. This explanation seems the only satisfactory one which can be given for these cases, and indeed they lend considerable weight to the theory as a whole. In the case, for example, of partial duplicity of a limb, it might be possible to suppose, leaving out of consideration, for the moment, other arguments which tell against such an explanation, that some other cause (*e.g.* irritation) had produced a division of the developing rudiment; but such an explanation will not account for cases of heterotopic redundancy, such, for example, as those of cephalomelus. Here we are forced either to suppose that all the rest of a second embryo has disappeared, with the exception of the one superfluous limb,—a cumbrous hypothesis,

[1] Vrolik gives it as a law, that the malformed parts are restricted to their determinative place according to what Fleischmann calls *lex topicorum*. It is evident, however, that this law is not without its exceptions.

for which there does not seem to me to be any valid evidence,—or to adopt some similar explanation to that given above. If, then, such an explanation best fits in with the facts relating to heterotopic redundancy, it is an additional argument in favour of applying it to those of homotopic. Additional evidence in favour of this theory is also, I think, to be obtained from the cases of partial formation of digits on the ends of imperfect limbs. Speaking of these rudimentary digits, Sturge (42) remarks, "It is very easy to account for them on the hypothesis of mal-development, for in that case they represent the amount of vitality left in the embryonic cells from which the limb should have developed. On this hypothesis, we should expect to find, as in fact have been found, many degrees of development, ranging from minute nodules, representing fingers at one end of the scale, up to extremities of limbs which differ but little from the hand at the other end." My colleague Mr Jordan Lloyd was good enough to place at my disposal a case of this kind. It was the lower limb of a child, much shorter than the other extremity, and was removed by him by amputation. It consisted of three rounded masses, separated from one another by constrictions, which looked as if they might have been formed by a tightly tied piece of cord, and which, in fact, were probably due to the constricting influence of bands derived from the amnion. On the distal and smallest of these tumours, there were five skin toes, perfect in shape, though exceedingly diminutive, and unpossessed of nails. The proximal tumour, which measured 12 × 7 cm., contained in its centre a part of the femur and some rods of cartilage which doubtless represented the remaining bones of the extremity. The remainder of this tumour, as well as the entire of the others, consisted of fat, with fibrous bands running through it. Eimer (43) considers these rudimentary fingers, formed after fœtal self-amputation *in utero*, as examples of the same power of recrescence which is met with in tritons and other forms. But it is not certain, I think, that they appear on truly amputated extremities. Some of the cases certainly seem to point to it. Thus a case described by Simpson (44) is "the stump of the left forearm of a fœtus of the seventh month, preserved in the Obstetric Museum of the University of Edinburgh. There are five small rudimentary

fingers, tipped with minute nails in the usual position, at the end of the stump. But the case is principally remarkable for the circumstance that the cicatrisation over the ends of the radius and ulna is not complete. There is an aperture at the end of the radius, through which the end of the bone can be felt when the point of a pin is passed through it. The ulna projects to the cutaneous surface of the stump, and has a small wound or circle of uncovered granulations still around it; or, in other words, the stump is as yet incomplete." It is to be remarked, that the crucial test of an intrauterine amputation is that the missing member shall be found in the membranes, a discovery which I do not think has been made in cases where rudimentary digits are present. However, leaving aside the question as to whether they appear in cases of intrauterine amputation,—a question which, if settled in the affirmative, would need some such explanation as Weismann has given for the phenomena of recrescence in tritons,—it is quite certain that such digits appear in a rudimentary but recognisable condition in cases like that described above by me, in which there is no suspicion of intrauterine amputation, as well as in a fully-formed state in some of the cases of phocomelia. Such a condition may be explained much as Sturge has done, but varying his phraseology, by supposing that whilst the other determinants of the limb had, for some cause, failed to develop, those of the digits had in part fulfilled their normal course. Thus we learn that a set of determinants may develop independently, although those with which they would normally be connected have failed to do so. And if determinants can so act in their normal position, it may reasonably be argued that they may also do so if, for some reason, they have taken up their position in some abnormal site.

Finally, as regards the subject of redundancies, it may be mentioned that, possibly on account of some faulty segmentation in the formation of the polar bodies, it almosts looks as if, whilst some of the normal determinants are absent, abnormal ones are present; in fact, if the hypothesis is not too venturesome, as if there had been a substitution of abnormal for normal determinants. Such a theory would account for the commonly observed presence of monstrosities of defect and of excess, present side by side in the same fœtus. The case

described at the commencement of this paper, where dignathism and polydactyly coexisted with defective formation of the external genitalia, is an instance in point.

## SECTION IV. GENERAL AND PARTIAL HYPERTROPHY.

It now only remains to say a few words respecting cases of macrosomia and partial excess of growth, as distinguished from superfluity of parts. Cases of this kind are so well known that I need not delay over their description. The latter condition has recently been fully dealt with by Humphry (45), who says that these cases "obviously consist in an excess, an abnormally excessive growth of a normal part of the body—an excess not depending upon any superabundance of nutritive supply or any modification of nerve-influence, but upon an excess, a want of due restraint, of that developmental force by which the several organs and structures acquire and maintain their proper dimensions and relations to one another, and by which their relative growth at different periods of life and under different circumstances (as of the genital organs at puberty) is determined. The nature of this force is a mystery, perhaps past finding out." The cases now under consideration differ essentially from those of duplicity. In the latter, superfluous determinants exist which need have no place in the former. To use a simile, suggested by Weismann's adoption of the term "the architecture of the germ-plasm," it is as if, in cases of duplicity, additional turrets and wings had been added to the edifice of the body by the action of the additional determinants; whilst in the other case, for some reason at present unknown, the walls of the building, or of a part of it, had been erected in a more massive manner than usually happens.

## SECTION V. CONCLUSIONS.

The views which I have ventured to put forward on the difficult subject of duplicity, in this and in my former paper, may be summarised as follows:—

1. The cause of double monstrosity is a superfluity of germ plasm (determinants) existing in the germ.
2. This superfluity of germ-plasm leads in the case of true

double monstrosity to a fission which is prior to that by which normal development is commenced.

3. The superfluity may possibly be traced to—
   (*a*) The retention of superfluous germ-plasm, owing to a faulty segmentation of the polar bodies.
   (*b*) The introduction of superfluous germ-plasm, from faulty segmentation in the formation of the spermatozoa.
   (*c*) The introduction of superfluous germ-plasm, by the entrance into the ovum of more than one spermatozoon.
4. The amount of duplicity depends upon the number of superfluous determinants retained in, or introduced into, the ovum.
5. In homotopic redundancy, the superfluous determinants follow the normal track in development; in heterotopic, an abnormal.
6. It is possible that absence of normal determinants may coexist with the presence of abnormal in the same germ.
7. In the case of parasites, degeneration may be an additional factor in the production of the condition.
8. Excess of growth without superfluity of parts depends upon different causes from those which produce double monstrosity.

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# LEFT VENA CAVA INFERIOR. By H. J. Waring, B.S., B.Sc., F.R.C.S., *Demonstrator of Anatomy, St Bartholomew's Hospital; Assistant Surgeon, Metropolitan Hospital.*

(From the Anatomical Department, St Bartholomew's Hospital.)

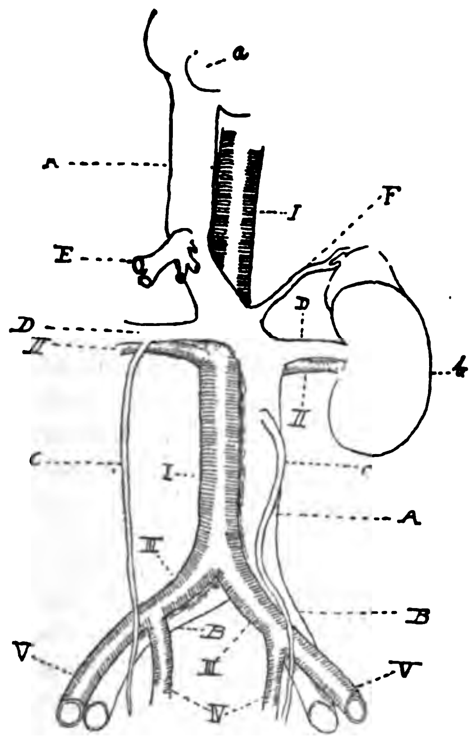
Many examples of double inferior vena cava have been recorded by Gruber, Kadzi, Nicolai, Petsche, Kollmann, Walter, and Walsham, but few, if any, records are to be found in anatomical literature of cases of a left inferior cava in which there was no transposition of viscera.

The following is the condition of the vena cava inferior which was found in a female subject dissected in the Practical Anatomy Room of St Bartholomew's Hospital during the past winter.

The inferior vena cava is formed by the junction of the two common iliac veins in front of the middle of the body of the fifth lumbar vertebra, and somewhat to its left side. The point of union lies directly behind the left common iliac artery, and about one inch below the division of the abdominal aorta. The right common iliac vein is formed by the junction of the right internal and external iliac veins just external to the sacro-iliac synchondrosis of that side. This vein lies behind the right internal iliac artery at its commencement, then to the inner side of the right common iliac artery, passing obliquely upwards and across the right extremity of the sacral promontory to the lower part of the body of the fifth lumbar vertebra, until it reaches the level of the middle of the body of this vertebra. At this point it passes to the left side of the middle line lying behind the left common iliac artery, and joining its fellow of the opposite side. The whole course of this vein measures two inches. The left common iliac vein commences behind the bifurcation of the left common iliac artery, and in front of the left sacro-iliac synchondrosis by the union of the left internal and external iliac veins. The vein passes vertically upwards, lying upon the left side of the body of the

fifth lumbar vertebra. At its commencement it lies behind the artery, but in its course upwards it immediately passes to its outer side, and when it is joined by the corresponding vein of the right side it is completely to the left of the artery.

The inferior vena cava thus formed passes vertically upwards for two inches. It is then joined on its left side by the left renal vein. In this part of its course it lies upon the front and left sides of the bodies of the fifth, fourth, and third lumbar vertebræ; to the right is the abdominal aorta, and to the left



*A*, inferior vena cava; *BB*, common iliac vein; *CC*, ovarian veins; *DD*, renal veins; *E*, hepatic vein; *F*, supra renal vein; *i*, abdominal aorta; *ii*, renal artery; *iii*, common iliac artery; *iv*, internal iliac artery; *v*, external iliac artery; *a*, right auricle; *b*, left kidney.

the left psoas muscle. Opposite the middle of the body of the third lumbar vertebra the left ovarian vein joins the inferior vena cava on its anterior surface (see figure *c*).

After receiving the left renal vein it passes obliquely across the anterior surface of the abdominal aorta to the right side of that vessel, and then lies upon the crus of the diaphragm. The oblique part at its commencement lies opposite the upper part of the third and the lower part of the second lumbar vertebræ, and the intervertebral disc between them. This oblique part measures 1½ inch in length. The right inferior angle of the oblique part is joined by the right renal vein, into which opens the right ovarian vein (see fig., *c*). Beyond this point the vena cava passes vertically upwards, lying upon the right crus of the diaphragm, and then grooving the liver, where it is joined by the hepatic veins, to pass through the vena caval aperture in the diaphragm and join the right auricle. This portion measures 3½ inches in length.

The other tributaries of the vena cava inferior have their normal distribution.

In the chest the azygos veins present nothing abnormal. There is no transposition of viscera. This most unusual position of the vena cava inferior is due to faulty development.

Different views are held by embryologists on the development of the vena cava inferior. According to Rathke, it grows out from the sinus venosus as an unpaired trunk, which passes backwards on the right side of the abdominal aorta and becomes united, by means of the common iliac veins, with the posterior cardinals where the latter are joined by the crural veins. The veins of the lumbar parietes open first into the posterior cardinals, next into the posterior vertebral veins, which partly replace the posterior cardinals, and finally into the unpaired trunk of the vena cava inferior. Hochstetter describes a short anterior and a long posterior portion of the vena cava inferior, each of which has a distinct developmental origin. The anterior portion appears as an inconspicuous vessel on the right side of the abdominal aorta in the tissue which lies between the two primitive kidneys; the posterior portion is developed out of the distal part of the right cardinal vein. The anterior portion, soon after it has been formed, unites with the two cardinal veins by means of cross branches at the level of the renal veins. This portion soon increases in size, and takes most of the blood from the lower part of the body back to the heart. The right

cardinal vein increases in size, whilst its fellow of the opposite side shrinks up and ultimately disappears. This change is due to the fact that the right cardinal vein is the line of direct prolongation of the anterior portion of the vena cava inferior, and also because in the pelvic region an anastomosis is formed between the two cardinal veins by means of which blood is conveyed from the left side to the right. Hence, according to this author, the portion of the inferior vena cava between its commencement by the union of the common iliacs and the point where the renal vein joins it above is formed from the right cardinal vein. The part above the renal arises from the unpaired vessel whose origin has been given above. Macalister's account is somewhat different from that of Hochstetter. He says that when the lower extremities are developed, two new appendicular veins are formed, which ascend and unite on the right side with the inferior or abdominal portion of the right cardinal, which thus becomes enormously enlarged, and which, passing between the two kidneys, receives the blood from them. At the upper part of the abdominal cavity a branch of communication, which forms a short cut to the sinus venosus behind the liver, becomes dilated to carry the blood of this channel into the heart, whilst the continuation of the abdominal into the thoracic cardinal vein diminishes to a rudiment. The dilated abdominal part of the right cardinal vein, together with the communication with the sinus venosus and the hinder part of the sinus venosus itself, form in the adult the vena cava inferior.

Hochstetter's account will well explain the condition of the inferior vena cava here described. During development, owing to some unexplained cause, the lower abdominal portion of the right cardinal vein had either not been formed or had become obstructed. The pelvic communication between the posterior portion of the two cardinals had been established and persisted as the portion of the right common iliac vein which lies upon the body of the fifth lumbar vertebra. The left cardinal vein in the lower part of its extent had become much dilated, and formed the portion of the inferior vena cava below its junction with the left renal vein. The oblique portion which crosses over the anterior surface of the abdominal aorta had been developed

from a dilatation of the anastomosis which is formed between the upper portion of the inferior vena cava and the left cardinal vein. The upper vertical portion had been formed by a dilatation of the small unpaired venous stem which appears in the tissue lying between the two primitive kidneys.

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# ON THE DEVELOPMENT OF THE BONES OF THE FOOT OF THE HORSE, AND OF DIGITAL BONES GENERALLY; AND ON A CASE OF POLYDACTYLY IN THE HORSE. By JOHN STRUTHERS, M.D., LL.D. (PLATE I.)

MY object in this communication is to show that, besides the well-known epiphysis at the proximal end, an early-coalescing epiphysis is present at the distal end of the first phalanx, fore and hind foot, and to remark on the significance of the presence of an epiphysis at the rudimentary end of the lesser metacarpal and metatarsal bones in relation to the descent of the horse. Also to record a case of polydactyly in the horse. Some remarks are added on the ossification of metacarpal and metatarsal bones and phalanges generally, in connection with the foregoing.

## (A) THE PHALANGES.

*First Phalanx.*—Figure 1 shows the position of the epiphysis on the phalanges and on the great metacarpal bone, as seen in longitudinal median section, in a foal a month before the full time of intrauterine life. There are seen the well-known distal epiphysis on the metacarpal and proximal epiphysis on the first and second phalanges, and a distal epiphysis on the first phalanx. I came upon the latter in the course of making, a number of years ago, a series of sections of the foot of the horse to ascertain the mode of development of the rudimentary metacarpal and metatarsal bones. The occurrence of this epiphysis had been overlooked owing to its early coalescence with the shaft. The coalescence has begun even before the full intra-uterine time, requiring section of the bones to be made for the distinct display of this epiphysis.

In the specimen figured, *a month before the full time*, the coalescence with the shaft is rather more advanced in the fore than in the hind foot; in the fore foot for about $\frac{1}{12}$ inch in depth before and behind; in the hind foot for a less depth in front (about $\frac{1}{24}$ inch), while, behind, the separating fissure runs

out showing itself on the surface of the bone for ⅛ inch on each side of the middle line.

In a specimen *at the full time* the coalescence is not quite so far advanced as in the last-mentioned one, and is rather more advanced in the hind than in the fore foot. In the fore foot it is for a depth of fully ⅛ inch in front, and the separating fissure runs out behind showing itself on the surface for about ¼ inch on each side of the median section. In the hind foot the coalescence in front is about the same, but the separation is seen behind for a shorter distance (about $\frac{1}{12}$ inch on each side of the section).

Viewed on the surface a fine suture is seen in these specimens running round the bone, separating the head from the shaft. This superficial line runs considerably higher at the sides than at the middle, so as to embrace the lateral tuberosities as well as the articular surface, and even at the middle it is higher than the fissure of separation seen in the sections, the epiphysis thus shelving over the end of the shaft. In a specimen a month after birth, fore and hind foot, this superficial line has disappeared in front and at the sides, but is still visible behind.[1]

*Second Phalanx.*—In regard to the development of this bone, Chauveau (*loc. cit.*, p. 115) remarks:—"It is usually developed from a single centre of ossification, though in many subjects there is a complementary nucleus for the superior articular and the posterior gliding surface." In all my young specimens there is a large completely separate *proximal* epiphysis, seen on all sides; in the sections seen to form a sixth part of the length of the entire bone; and projecting out behind as a thickened crest

[1] The presence of a distal epiphysis on the first phalanx of the foot of the horse was demonstrated by me from these specimens at the meeting of the *British Association for the Advancement of Science* at Aberdeen in 1885 (*Report* for 1885, p. 1103). In a subsequent edition of Chauveau's *Comparative Anatomy of the Domesticated Animals* (English edition by Fleming 1891, of the French edition of the previous year) it is remarked (p. 115) in regard to the horse:—"The first phalanx is a very compact bone, and is developed from two points of ossification, one of which is for the superior extremity alone. Professors Vachetta and Foliata, of Pisa, assert that this bone, as well as the second phalanx, has three centres of ossification during uterine life." My specimens, although they are fully macerated and show all the markings well, do not afford reliable evidence that the second phalanx has had a distal epiphysis. I was indebted to Professor Dewar, of the Edinburgh Veterinary College, for procuring me a number of the foals' limbs from which my specimens were prepared.

which supports the surface termed in veterinary anatomy the "posterior gliding surface," mentioned in the above quotation. The appearances in my specimens that might be taken for traces of a *distal* epiphysis on this bone are doubtful. The specimen figured (fig. 1) shows near the extreme end of the section ($\frac{1}{10}$ inch, the whole bone scarcely an inch in length) a furrow, $\frac{1}{4}$ inch in length, intersecting nearly half of that part of the head. In a specimen at the full time, a special row of cancelli may be recognised at the corresponding part in the fore foot, but there is no trace in the hind foot in either specimen. Nor is there on the surface. There is a fine raised line, seen behind, passing upwards and outwards from the middle, at the edge of the articular surface, to the upper lateral angle, extremely like the suture of a coalescing epiphysis, but on a little gentle scraping with the knife this raised line disappears leaving no trace of a suture. This quasi-epiphysial line would give the greater part of the bone to the supposed distal epiphysis. I notice this detail as the appearance is very apt to mislead. It will require younger specimens than mine to prove satisfactorily the presence of a distal epiphysis on the second phalanx.

*Third Phalanx.*—The third phalanx is always described in works on veterinary anatomy as developed from one centre only. If this statement is founded on the observation of sections at early periods of intrauterine life, it is remarkable that a proximal epiphysis should be absent on this very great phalanx in the horse while it is present on even reduced distal phalanges in other mammals.

## (B) THE LESSER METACARPAL AND METATARSAL BONES.

Figure 2 shows the position of the epiphyses on the metacarpal bones and phalanges in a young horse, reduced to about $\frac{1}{4}$ the natural size. The epiphysis of the lesser metacarpal is seen to be situated not at the upper functional end, but at the distal rudimentary end. To illustrate the interpretation of this interesting fact is given, in figure 4, a copy of Professor O. C. Marsh's much reduced figure of the fore foot of *Hipparion*.[1]

[1] *American Journal of Science and Arts*, vol. xvii., June 1879, p. 498.

There it is seen that the lateral metacarpals in that extinct three-toed horse extend, of good size, down to near the fetlock and support lateral toes, each of three phalanges. The descent of the horse of the present time may be said to be now well established, above all by the researches of Professor Marsh; and we have, it seems to me, in the lingering of the epiphysis at the distal end of the lesser metacarpals and metatarsals an additional and interesting link in the chain of evidence.[1]

*Condition of these bones, and variation at the distal end.*—At their upper end these bones are large, and take part in the formation of the carpo-metacarpal and tarso-metatarsal synovial articulations. They have also, continuous with these joints, a small lateral synovial articulation with the head of the great bone. Any vertical movement thus permitted is limited by the interosseous fibrous tissue that binds their flattened anterior surface to the great bone, and not unfrequently they become ossified to the great bone along the upper or middle third of their shaft. My specimens show this to be the case more especially with the internal, the larger, of these bones. In one of these the ankylosis extends down even to the commencement of the button, without appearance of ostitis or of what is termed "splint." Generally, these bones on their lower third or fourth are not ankylosed to the great bone, but are close to it, and they are there flattened and greatly reduced in bulk. There, on the outer metacarpal, the breadth may not exceed $\frac{1}{8}$ inch, in contrast with a thickness of $\frac{1}{2}$ inch on the upper third.

The small, generally flattened, almond-like terminal tubercle, or "button," may stand out a little from the great bone, but the projection that may be felt in the living animal is rather owing to the greater convexity of the posterior border. It varies a good deal in size, but $\frac{1}{2}$ inch in length by $\frac{1}{4}$ or $\frac{1}{3}$ inch in breadth may be taken as an average size, the breadth varying more than the length. It rises rapidly from the reduced shaft especially at the posterior border.

[1] That the "tubercle," or "button," at the distal end of these bones may be developed separately has long been noticed in books on veterinary anatomy. Chauveau (*loc cit.*, p. 112) remarks of these bones that they "are developed from only one ossifying centre. Not unfrequently, however, the tubercle is formed from a special centre." But the significance of this fact in relation to the evolution of the horse has been overlooked.

As to relative length and thickness the lesser metacarpals and metatarsals cease at about the beginning of the lower fourth of the great bone, with some variation in either direction, and with some variation as to whether the internal or the external goes farthest down. According to Chauveau (*loc. cit.*, p. 112 and p. 149), in the fore foot the internal is "always the thickest, and often the longest," and in the hind foot "the external is always longest, if not thickest." But in two of my specimens, one at, the other a month after, the full time, the internal metatarsal is longer as well as thicker than the external. Among minor variations as to relative length, what it is of interest to recognise is their relative size—the fact that the internal is the thickest in both fore and hind foot—taken in connection with the fact that in cases of extra digit in the horse the additional toe is on the inner side. In the fore foot, the internal, on its lower third, is twice or thrice as thick as the external, and, as far as my less numerous specimens of the hind foot show, the internal likewise in that foot is, young and adult, decidedly thicker than the external. This difference in size between the two bones at their lower end is represented in fig. 3, but is seen likewise along the shafts.

*Ossification of the distal epiphysis.*—In the specimens before or at the full time, the epiphysis had not passed beyond the cartilaginous stage. In one, at a month after birth, ossification has begun in the internal metatarsal (left side only obtained) but not in the external. On the distal inch of the shaft, that metatarsal is three times as thick as the external. In a specimen, from which figs. 2 and 3 are drawn, the exact age of which was not obtained, but which I take to be within a year after birth, the lines of union of the epiphysis of the great metacarpal and of the phalanges are still visible; the epiphysis of the internal lesser metacarpal is consolidating, the line still visible, but on the external bone, and on both lesser metatarsals, the epiphysis is still quite separate. What appears as the button in the adult is in part formed by the shaft (varying, but about $\frac{1}{4}$ to $\frac{1}{3}$), which enlarges a little at the very end to meet the epiphysis. In the dissection of these young specimens the fibrous tissue from the end of the epiphysis was seen to expand into a fascia. Dissection, whether in the young or in the adult,

furnishes no adequate functional explanation of the presence of the lower parts of these bones.

## (C) Case of Polydactyly in the Horse.

Figure 5 shows the bones and their epiphyses, as now present in the specimen, reduced to ½. The distal phalanx of the great toe had been removed with the hoof, and it is uncertain whether the extra digit had more than the proximal phalanx, although the toe is large for an extra digit. I was indebted for this specimen to the late Mr Bruce, V.S., New Deer, in whose possession it had been for twenty years as a dried preparation. The other fore foot and both hind feet were normal. From the condition of the epiphyses, I would infer that the foal had reached the full time or more. The following are the measurements, given in inches, and the characters of the bones.

*Great Metacarpal* :—4 inches present, including ¾ inch as epiphysis. Probable length of bone, 9 to 10 inches. At lower end, breadth 1½, thickness 1; at 4 inches up, breadth and thickness equal, ¾. *Lesser Metacarpal* :—At top of specimen, 3½ inches up, breadth ⅜, thickness over ½ inch. At lower end, breadth 1, thickness ¾. Length of epiphysis almost same as that of great bone. Last inch of shaft increases rapidly in breadth to meet this large epiphysis. Bone extends down to within ¾ inch of end of great bone, on level with junction of epiphysis of latter with shaft. The two bones are flattened against each other throughout. Were separated only by their periosteum, and were united by fibrous bands before and behind. In the moist state they could be moved on each other. Sesamoid bones present in both toes, the sesamoid next the other toe about twice the size of the other in both toes.

*Phalanges. Great toe.* (1) *First phalanx* :—Length 2¾ including ⅜ as epiphysis; breadth, at upper end 1½, at distal end 1¼, at middle ⅞; thickness at middle, nearly ⅞. Traces of distal epiphysis obscure. On distal half of outer side there is a rough elevation. (2) *Second phalanx* :—Length in front 1⅛, behind 1¼; breadth 1¼; thickness 1. Proximal epiphysis united in front, but suture well marked behind. Pulley on distal end very shallow and very unequal, on side towards lesser toe large and bulging. Excavations at anterior boundary of articular surface might be mistaken for traces of a distal epiphysis. Upper surface rough and elevated, like roughness noted on part of first phalanx, apparently from abnormal action.

(3) *Third phalanx* wanting in the specimen, probably removed with hoof, but articular surface on second phalanx shows that a third phalanx was present. Navicular bone, presence was noted in the dissection, but not now present.

From these measurements it is seen that the whole of the bones of

this great toe differ from the normal condition in their unusual narrowness compared with their length and thickness. In a normal specimen, at the full time, the measurements at the lower end of the great metacarpal are—breadth 2, thickness $1\frac{1}{4}$; in this polydactylous specimen they are—breadth $1\frac{1}{2}$, thickness 1. First phalanx in the former, length $2\frac{1}{2}$; at middle, breadth $1\frac{1}{2}$, thickness $\frac{7}{8}$; while in this polydactylous specimen these measurements are—length $2\frac{3}{4}$, breadth $\frac{7}{8}$, thickness nearly $\frac{7}{8}$.

*Lesser Toe—First Phalanx.*—Length, including $\frac{3}{8}$ as epiphysis, $2\frac{1}{4}$; breadth, at upper end 1, at distal end $\frac{5}{8}$, at narrowest part, below middle, $\frac{4}{8}$; thickness there, $\frac{3}{8}$. The whole of the shaft is smooth; distal end rounded on all sides, more sloped off on side furthest from great toe. Most of end now as if articular lamina worn off, but patch like articular surface remains on part next great toe.

I am unable to say with certainty whether the second and third phalanges were present. The great size of the first phalanx for that of an extra digit would warrant the supposition that they had, but on dissection, after soaking the dried specimen in water, there was only a tuft of fibrous tissue at the end of the first phalanx, and the only flexor tendon I saw was distinctly inserted along the distal half of the phalanx on the side next the great toe, going to the end. The two extensor tendons seen, each $\frac{1}{3}$ inch in breadth, and separate up to the top of the preparation, also appeared, after uniting, to end on the first phalanx. The one next the great toe sent a slip to join the extensor of the great toe. The dissection of such a long-dried preparation, with most of the soft parts removed, was necessarily unsatisfactory.

We have in this specimen an extra digit in the horse attaining fully the size of the lateral digits in the Hipparion, indeed a larger size, for the metacarpal bone is at 4 inches up a third the breadth, and at the lower end over half the breadth of the great metacarpal, with proportionate thickness. Its first phalanx is large, reaching to near the middle of the first phalanx of the great toe, while in Professor Marsh's figure of Hipparion, the distal end of the first phalanx reaches to only a little beyond the upper end of that of the great toe. In the figure given by Professor Marsh (*loc. cit.*, fig. 2) of the "fore foot of horse with extra digit," the metacarpal and the three phalanges are as slender as in his figure of Hipparion. My specimen (and the figure, fig. 5) wants the external lateral metacarpal bone, which is represented as normal in Professor Marsh's figure 2, above referred to, but there is on the back of the great metacarpal bone a narrow elongated impression (a slight roughness, but quite distinct) exactly where the lower part of a normal external metacarpal would lie, terminating $2\frac{1}{2}$

inches from the lower end of the great bone. I am not able to say definitely that this extra digit is internal to the great one—that it is, as usual, digit II, not digit IV—in the absence of the upper end of the bones, and owing to the abnormal proportions at the lower end of the great metacarpal.[1]

## (D) Remarks on the Development of Digital Bones generally.

There need be no difficulty in receiving a statement of the pre-

[1] Professor Marsh (*loc. cit.*) points out that the extra digit is generally on the inside, contrary to the general law of the order of reduction from the five-toed foot, and discusses the possible reasons. He gives a case, with figure, of a living horse examined by him, with this internal extra digit on all the feet, fore and hind, and a historical notice of cases of polydactyly in the horse. In the case of a fœtal horse recorded by Geoffroy St Hilaire, there were three nearly equal toes on one fore foot, and two on the other. Professor Marsh mentions, as reported to him, a case the same as the last in a colt, and one of a mare with three toes on each fore foot, and a small extra toe on each hind foot. The most frequent occurrence is that of an extra digit on one fore foot, next on both fore feet, and then on one or on both hind feet. Professor Marsh's researches, showing the successive stages in the descent of the horse, are profoundly interesting, and his collection at Yale University is well worth a visit. In European museums specimens of the foot of Hipparion may be seen in the British Natural History Museum and in Paris, but the best I have seen are in Munich. That valuable palæontological museum contains numerous specimens, including the feet and jaws, of two species of Hipparion, obtained from near Athens. By the kindness of Professor Zittel I was enabled to examine these specimens when I visited the museum in 1872. The mounted skeleton of *Hipparion gracile*, in parts "restored," in that museum, is a striking object.

I may refer here to a case I recorded many years ago (*Edinburgh New Philosophical Journal*, 1863) in which one fore foot of a two-year-old filly, which I saw and examined in Northumberland, presented two equal toes. The foot resembled that of an ox, the toes separate, each with its three movable phalanges, and the great metacarpal bone felt as if bifurcated at the distal end. The two lesser metacarpal bones were felt to terminate at about the usual place in both fore limbs. I had only the examination of the living animal, as my efforts to obtain the limbs for dissection when the animal died were unsuccessful. Light is thrown on the probable internal arrangement in this case by a specimen I afterwards, in 1871, saw in the museum of the Veterinary School in Berlin. In it both fore feet have two toes, the inner toe about one-third less than the outer. The great metacarpal is bifurcated at its distal end, as in the ox, supporting the two toes. The lesser metacarpals are normal. Another specimen in that museum also shows an extra inner toe on both fore feet, the lesser toe, metacarpal and three phalanges, about one-third the size of the great toe. The outer lesser metacarpal is normal. Although the horse is young, the metacarpal supporting the extra toe in the left foot is united for over half its length to the great metacarpal. These cases, I understand, are published but I have not the reference. The museum, an extensive and valuable one, contains other specimens of digital variation in the horse and in other domestic animals.

sence of an epiphysis at both ends of a phalanx or metacarpal or metatarsal bone if founded on the evidence of sections. In 1863 I recorded [1] the observation that an epiphysis is present at both ends of the phalanges and metacarpal bones in cetacean digits. This may be easily seen in the common porpoise, or on a larger scale in the common Globicephalus. In the longest digit of the latter, with its 14 bones, including the "metacarpal," ossified epiphyses are easily seen on both ends of all of them, except on the last two very small phalanges. On section, the separation of the epiphyses from the shaft is seen to go through and through. In all the whalebone whales I have examined, the nodes at the ends of the digital bones remain cartilaginous.

The late Professor Allen Thomson made, in 1868, in this *Journal* [2] a valuable contribution to our knowledge regarding the development of digital bones.

In all cases which he examined at a sufficiently early age (about the 7th or 8th year, and in some later) he found evidence of a distal epiphysis on the first metacarpal and first metatarsal bones of Man, and calls attention to Albinus (1737) having been aware of this fact. He also figures indications of the occurrence of a proximal epiphysis on the second metacarpal bone, and had seen very faint indications of the same on the third metacarpal. In an accompanying note, Sir George Humphry confirms the above observation in regard to the first metacarpal and metatarsal and the second metacarpal, from the bones of a child æt. 10 years.

Allen Thomson found, further, the following in various mammals, in addition to the well-known epiphysis. Twice in the common seal, but in the hind foot only, distal epiphyses, of which he gives figures, on all the phalanges except the terminal ones, and on the first metatarsal; that is, epiphyses on both ends of all these bones in the hind foot of the seal, being an approach to what I had found in cetacean digits, except that a proximal epiphysis was not seen on the four outer metatarsals in the seal. Further, he found evidence of the occurrence of a distal epiphysis on the first metacarpal of a young chimpanzee, an elephant, a kangaroo and a koala; and mentions that Dr Murie informs him that he had found a distal as well as a proximal epiphysis present on the first metacarpal and first metatarsal in the young orang and chimpanzee, and the same in the Otaria jubata and in a young walrus on the first metacarpal, but on the first metatarsal only the usual proximal epiphysis. Still more inter-

[1] "On Variation in the Number of Fingers and Toes, and in the Number of Phalanges in Man," *Edinburgh New Philosophical Journal*, vol. xviii., 1863.

[2] "On the Difference in the mode of Ossification of the First and other Metacarpal and Metatarsal Bones," vol. iii.

esting, Allen Thomson found in an ornithorhynchus, in which ossification was far advanced, in both fore and hind feet "indications of distal epiphyses on all the five metacarpal and metatarsal bones including the first; and, what is still more exceptional, besides the usual proximal epiphyses of the first metacarpal and metatarsal, there are also grooves separating epiphyses on the proximal ends of the second and third bones of the series, and less obviously of the fourth and fifth bones."

In view of these observations of Allen Thomson, made with that esteemed author's usual caution, a field for further research is opened up, and we may expect to hear of the presence of early-coalescing epiphyses on those ends of metacarpal and metatarsal bones and phalanges which have hitherto been supposed not to have had epiphyses. There will remain, however, the fact that the late-coalescing epiphysis is distal on metacarpal and metatarsal bones, except on the internal in the five-toed mammals, and proximal on these latter bones and on phalanges.

The reason for this general fact is not apparent from the point of view of function. If determined by the relative length and size attained by the bone, we would expect a late-coalescing epiphysis to occur at both ends of the great metacarpal and metatarsal in the horse and ox. If determined by exercise at the joint, we would expect the late-coalescing epiphysis to be at the distal, not the proximal, end of the first metatarsal bone in Man, even more so than in the case of the four outer metatarsals, unless on the supposition of his descent from an ancestor with prehensile foot. If determined in any way by function or by size, we would expect the epiphysis to be at the upper end, not at the lower rudimentary end, of the lesser metacarpals and metatarsals of the horse. Descent from pre-existing forms comes in here as the explanation, and this explanation may have a wide application. Among the Cetacea, the digital bones, like those of the forearm and arm, show the double epiphysis in a simple limb, and Allen Thomson's observation on the ornithorhynchus is interesting as showing the occurrence of double epiphyses in one of the lowest mammalian forms. Why in the higher forms, with complex limb activities, one end of a bone should have gained an advantage by the early coalescence or disappearance, or by the late coalescence, of an epiphysis, remains an interesting question for inquiry.

It may be remarked, in conclusion, that the demonstration of the occurrence of an epiphysis also on the distal end of the first bone of the pollex and hallux does not necessarily, as Allen Thomson's remarks seem to imply, dismiss the view that it is the "metacarpal" and "metatarsal" bone that is wanting. There remains the fact that the late-coalescing epiphysis is proximal on them as on the phalanges. If development is not to count, it becomes merely a question of the most convenient names, and that former discussion may be closed with the remark that the view to take is, simply, that the third phalanx has not been formed.

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## EXPLANATION OF PLATE I.

The letters *p*, *e*, and *d*, *e*, on all the figures signify *proximal epiphysis* and *distal epiphysis*; the numerals 1, 2, and 3, indicate, respectively, the first, second, and third *phalanges*.

Fig. 1. Reduced to $\frac{1}{2}$. Median longitudinal section of the great and one of the lesser metacarpal bones, and of the phalanges of a foal a month before the full time. In the great, *g*, the position of the medullary canal and foramen are seen; in the lesser, *l*, cancellous tissue is seen at the thicker parts of the bone; the epiphysis, *d*, *e*, not yet ossified. On the first phalanx, 1 of *g*, is seen a distal as well as the proximal epiphysis, the distal epiphysis consolidated near the surface. On the second phalanx is seen a short faint line that might be taken for an indication of a distal epiphysis. The medullary cavity in each of the three phalanges is seen. *S*, section of one of the sesamoid bones at the fetlock joint; *s*, navicular sesamoid bone.

Fig. 2. Reduced to about $\frac{1}{3}$. Internal lateral view, in outline, of right fore foot of the same parts in a young horse within the first year. Great metacarpal, *g*, thickness of upper part of shaft in part concealed by the lesser metacarpal. On the lesser metacarpal, *l*, (the internal one is that presented in this view,) the epiphysis, *d*, *e*, now ossified and about to consolidate with the shaft, is seen to be at the rudimentary end of the bone. The small size of the bone on its lower third is seen. *S*, internal sesamoid bone; *s*, navicular sesamoid bone.

Fig. 3. Natural size. Lower part of the two lesser metacarpals from the same horse as fig. 2, as seen in lateral views, posterior borders, the most convex, towards each other. The much greater size of the internal bone is seen. The shaft is seen to enlarge to meet the epiphysis, forming part of the "button" at the end of the consolidated bone.

Fig. 4 is Professor Marsh's much reduced figure of the fore foot

of *Hipparion* (*loc. cit.*, p. 498) copied here for illustration of fig. 5, and to show how the occurrence of the epiphysis at the rudimentary end of the bone in the modern horse may be accounted for.

Fig. 5. Reduced to ½. Anterior view of the parts in a specimen of extra toe in a young horse. The greater metacarpal bone, *g*. The lesser metacarpal, *l*, much enlarged, carrying the extra toe. Third phalanx of great toe, lost with the hoof, shown in dotted lines. Rough marks are seen on the 1st and 2nd phalanges, the latter excavated. A second and third phalanx for extra toe shown in dotted lines, ?, to indicate that they were not present in the preparation. The dotted line, $l^a$, indicates where the normal lesser metacarpal bone has lain, but it is not present in the preparation.

Fig. 5*a*. Horizontal section of the two metacarpal bones of the last figure, where they had been divided four inches above the fetlock joint of the great toe. The flattened adaptation of their contiguous surfaces is seen, and the medullary cavities. The lesser bone about ⅓ the size of the greater.

EDINBURGH, *August* 1893.

FOURTH ANNUAL REPORT OF THE COMMITTEE OF COLLECTIVE INVESTIGATION OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND FOR THE YEAR 1892–93.[1] Reported by ARTHUR THOMSON, M.A., M.B., *Lecturer on Human Anatomy, University of Oxford.*

THE following questions were issued by the Committee of Collective Investigation early in October 1892:—

1. The condition of the os styloideum as attached (*a*) to the III metacarpal; (*b*) to the magnum; (*c*) to the trapezoid; (*d*) or free.
2. The frequency of the ossification of the pterygo-spinous ligament (Civinini), and its relation to the branches of the inferior maxillary nerve.
3. The arrangement of the branches of the right bronchus and their relations to the pulmonary artery.
4. The disposition of the spongy bones and meatuses of the nose, with especial reference to a fourth (highest) meatus.

Replies have been received from fifteen of the thirty-nine institutions to which notices were sent in the subjoined list. The schools which have contributed to the present inquiry are distinguished by an asterisk. Despite the fact that there is a slight falling off in the number of contributors, the Committee trust that the interest in the work is still maintained. The Secretary reports that several teachers have written to him expressing their regret that, from unavoidable circumstances, they have this year been unable to support the scheme.

*St Bartholomew's Hospital, London.
*Charing Cross Hospital, London.
St George's Hospital, London.
Guy's Hospital, London.
King's College, London.
London Hospital, London.
St Mary's Hospital, London.
*Middlesex Hospital, London.
*St Thomas' Hospital, London.
*University College, London.
Westminster Hospital, London.

[1] The Third Annual Report appeared in the *Journal of Anatomy and Physiology*, vol. xxvii., January 1893.

*London School of Medicine for Women.
Cook's School of Anatomy.
*University of Oxford.
*University of Cambridge.
*Queen's College, Birmingham.
Bristol Medical School.
School of Medicine, Yorkshire College, Leeds.
School of Medicine, University College, Liverpool.
*The Owens College, Manchester.
Medical School, Firth College, Sheffield.
University of Durham School of Medicine, Newcastle-on-Tyne.
*University of Edinburgh.
School of Medicine, Royal College of Surgeons, Edinburgh.
School of Medicine, Minto House, Edinburgh.
University College, Dundee.
School of Medicine for Women, Edinburgh.
*University of Aberdeen.
*University of Glasgow.
Anderson College, Glasgow.
St Mungo's College, Glasgow.
Western Medical School, Glasgow.
*School of Physic, Trinity College, Dublin.
Carmichael School of Medicine, Dublin.
*Catholic University School of Medicine, Dublin.
Royal College of Surgeons, Ireland.
Queen's College, Belfast.
Queen's College, Cork.
Queen's College, Galway.

# REPORT.

## QUESTION I.

### The condition of the os styloideum as attached (*a*) to the III metacarpal; (*b*) to the magnum; (*c*) to the trapezoid; (*d*) or free.

The following gentlemen have sent in replies :—

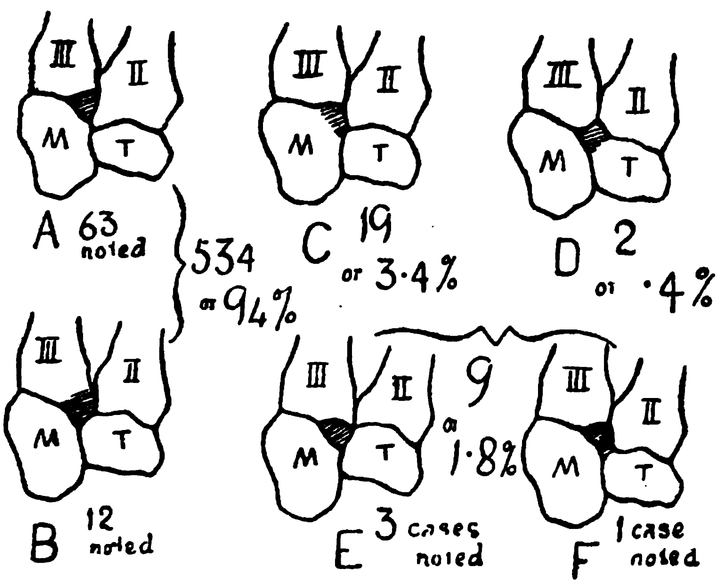
Messrs Robert Friel, Trinity College, Dublin; J. P. Frengley, Medical School, Catholic University, Dublin; J. R. Liddell, University of Edinburgh; John Morton, University of Glasgow; J. W. Wesley, University College, London; F. G. Parsons, St Thomas' Hospital, London; J. P. Hall, The Owens College, Manchester; A. Eichholz, University of Cambridge; Chas. Gibbs, Charing Cross Hospital; Joseph Ganner, Mason College, Birmingham; Jas. Gillespie, University of Aberdeen; Gordon Brodie, Middlesex Hospital; W. M'Adam Eccles, St Bartholomew's Hospital, London; H. Webb-Ware, University of Oxford; and Mrs Flemming and Miss Bale of the London School of Medicine for Women.

Records of 564 specimens examined have been received. The results have been tabulated into six groups, figured on Table I.: A and B are the conditions which most frequently occur. In them the os styloideum is fused with the base of the III metacarpal bone. This happened in 534 of the cases. A differs from B in that the styloid process of the III metacarpal does not articulate with the trapezoid, as is the case with B. Special attention has been drawn

to this difference in the returns of Messrs W. M'Adam Eccles, of St Bartholomew's Hospital, and J. P. Frengley, of the Medical School, Catholic University, Dublin; in a total of 76 cases examined by them, the condition figured A occurred 63 times, that in B 12 times.

Fusion of the os styloideum with the os magnum was described in 19 instances out of the total 564 cases inspected, yielding a percentage of occurrence of nearly 3·4. This class of case is figured C in the table: the part of the os magnum which is formed by the fused os styloideum is shaded.

TABLE I.—*Variations in the Form of the Os Styloideum. Total Number examined*, 564.




In the figures the part corresponding to the os styloideum is shaded. A and B represent varieties of the os styloideum fused with III metacarpal. See text. C, os styloideum fused with magnum. D, os styloideum fused with trapezoid. Figs. E and F represent varieties of free os styloideum, of which there were 9 examples of that number. Sufficient details are only given in 4 cases to enable them to be classed into groups E and F.

Two instances only of fusion of the os styloideum with the trapezoid are recorded, barely ·4 per cent. of all the specimens examined; and in one of the cases so recorded the tubercle thus formed was in part made up by a corresponding projection of the os magnum. This condition is represented in figure D of the table.

The os styloideum was found free in 9 instances, or 1·8 °/o, shown in figures E and F of the table. Mr W. M'Adam Eccles, of St Bartholomew's Hospital, who records 4 examples of a free os styloi-

deum, draws attention to a difference which may occur in the articulations of the ossicle. These differences are shown in figures E and F. The former (E) represents the arrangement when the os styloideum articulates with the os magnum, trapezoid, and III metacarpal. This was the case in three instances, whilst the latter (F) displays the ossicle articulating with the magnum, trapezoid, and II and III metacarpal bones. This condition Mr Eccles records in one instance. The same observer notes that in the cases in which the os styloideum was free the bone was in all cases firmly united to the III metacarpal by ligament, but "there seemed to be an entirely distinct synovial cavity between them.".

In this connection Mr Eccles furnishes some interesting details regarding the insertion of the tendon of the extensor carpi radialis brevior. He writes as follows:—

(*a*) "In forty-four cases there was the usual insertion of this tendon into the base of the styloid process of the III metacarpal bone, with a small bursa intervening between the tendon of the upper part of the process, which in six cases definitely communicated with the synovial cavity of the articulation between the II and III metacarpal bones."

(*b*) In six cases the tendon was also partly inserted into the II metacarpal bone, about the same level as its insertion into the III; in one of the six the greater part of the tendon was attached to the ulnar side of the base of the II, only quite a small slip passing to the base of the III. In this case the bursa was over the II, and not the III metacarpal bone.

The St Bartholomew's report was beautifully illustrated with sketches by Mr Hearn, a student of the school.

Mr C. Gibbs, of Charing Cross, in his notes draws attention to the occurrence of a tubercle, in one instance formed by the os styloideum on the III metacarpal bone, and a projection on the os magnum, which appeared continuous with it until the ligaments were removed. In another case the tubercle was formed by the styloid process of the III metacarpal and portions of the os magnum and trapezoid. The same observer describes an example of the os styloideum fused with the III metacarpal by a distinctly constricted neck, which, however, was not coated with cartilage: the proximal extremity of the process articulated with the dorsal surface of the os magnum by a small facet.

## Question II.

The frequency of the ossification of the pterygo-spinous ligament (Civinini), and its relation to the branches of the inferior maxillary nerve.

Returns in answer to this question have been received from—

Messrs F. G. Parsons, St Thomas' Hospital; J. R. Liddell, University of Edinburgh; J. P. Hall, The Owens College, Manchester; James Gillespie, University of Aberdeen; Chas. Gibbs, Charing

Cross Hospital; R. A. Bennett, Mason College, Birmingham; R. C. Bailey, St Bartholomew's Hospital; Gordon Brodie, Middlesex Hospital; G. F. Blacker, University College, London; J. Yule Mackay, University, Glasgow; and Mrs Flemming and Miss Bale, of the London School of Medicine for Women.

Out of a total of 218 specimens examined, the ligament, as figured in B, Table II., was described as occurring 141 times; partial ossification, as shown in figure C, was noted in 21 instances; and complete ossification was recorded in 6 cases, as represented in D. In 30 preparations no trace of a ligament could be found, and in 13 cases the structure was ill-defined, and described as membranous. Figure A includes both these conditions.

Dr Yule Mackay, of Glasgow University, in his report on this subject, writes:—

"I have found two ligaments in the neighbourhood of the foramen ovale.

"1. A pterygo-spinous ligament attached in front to the posterior edge of the external pterygoid plate, at a spot which appears, when the plate is viewed from the outer surface, to be placed about the line between the upper and middle thirds; attached behind to the spine of the sphenoid. It is very variable in thickness, but was found in all the cases, 13 in number, in which it was sought for. In 7 of the 13 cases the band was exceedingly slender, of moderate strength in 3 cases, well marked in 1, and was ossified as a slender bar in 2 cases (the right and left of a male subject).

"2. (Pterygo-sphenoidal) attached in front to the posterior margin of the external pterygoid plate, about midway between the place of attachment of the pterygo-spinous ligament and the upper extremity of the plate; attached behind to the under surface of the great wing of the sphenoid, a little in front of and external to the foramen spinosum."

"This band was sought for in 15 cases, and was found in 5 of these (occurring in one subject on both sides); in one of the five cases the ligament was represented by a slender band, in two it was of considerable breadth and formed of strong shining fibres; in two, whilst also strongly marked, it was partly ossified from the front; in the four cases in which it was well developed, fibres of the external pterygoid muscle took origin from it."

The relation of these ligaments will be further noted when the relations of the nerves are considered. Similarly, Mr R. A. Bennett, of the Mason College, Birmingham, records a differentiation of the ligament into two bands, though he furnishes no precise details as to their attachment.

Nine instances are recorded in which muscular slips either replaced or supplemented the ligament. These are thus described. Mrs Flemming and Miss Bale, of the London School of Medicine for Women, write:—"In 3 cases the ligament was represented apparently by muscular tissue." Mr Gordon Brodie, of Middlesex Hospital, records 3 cases in which there was a small muscle stretching across from the spine of the sphenoid to the junction of the upper and

Distinct bony prominences at the places of attachment of both extremities of the ligament were found in 7 cases, from 5 skulls. A distinct prominence at the place of attachment of the anterior extremity of the ligament was found in 48 cases (symmetrical in 17 skulls).

A distinct projection forward from the place of attachment of the posterior extremity of the ligament was found in 3 cases from different skulls.

2. Pterygo-sphenoidal: in the 80 skulls examined this was found as a complete bony bar; in 1 case on the left side.

Distinct bony prominences at the places of attachment of the anterior and posterior extremities of the ligament were found in 9 cases (symmetrical in 2 skulls); in one of the 9 the bar was almost complete.

A prominence at the place of attachment of the posterior extremity of the ligament was found in 12 cases (2 skulls symmetrical). At the place of attachment of the anterior extremity of the ligament a prominent bony spicule was found in one case. "It is to be noted that the anterior extremities of the two ligaments lie very close to one another; and when only one bony prominence is present, it is sometimes difficult to know to which ligament to assign it."

## Question III.

### The arrangement of the branches of the right bronchus, and their relations to the pulmonary artery.

Replies to this question have been received from—

Messrs Gordon Brodie, Middlesex Hospital; J. P. Hall, The Owens College, Manchester; J. R. Liddell, the University of Edinburgh; F. G. Parsons, St Thomas' Hospital; P. J. Fagan, Medical School, Catholic University, Dublin; Alfred Demsey, University College, London; Alfred N. Friel and D. F. Walker, Trinity College, Dublin; Geo. Lamb, University of Glasgow; Joseph Ganner, Mason College, Birmingham.

Observations have been made in 130 subjects. In 110 instances there was an eparterial bronchus on the right side, a condition represented in figure A, Table III. In 13 of the bodies examined the superior branch of the pulmonary artery lay in front of and on the same level with the bronchus to the superior lobe of the right lung (figure B, in Table III.).

The superior branch of the pulmonary artery is recorded as occupying a superior position to the eparterial (?) bronchus in 6 cases.

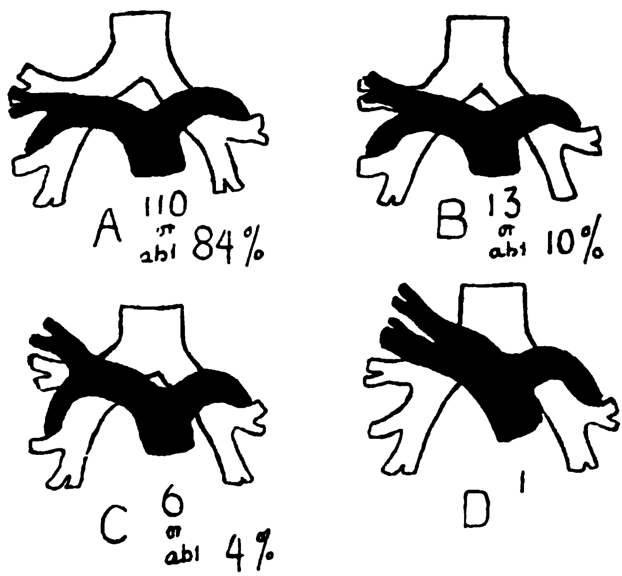
Mr Liddell, of the University of Edinburgh, thus describes two of the cases in which this happened, thus:—"The right pulmonary artery bifurcated, one branch going *above* and one below the eparterial bronchus."

Another case is recorded by Mr Liddell, in which the right pulmon-

ary artery passed across the trachea above its bifurcation. It then divided into two branches. This has been figured in the table as type D. Unfortunately, Mr Liddell supplies no further information as to the course taken by the arterial branches—whether they passed down behind or in front of the highest bronchus.

In the report furnished by Messrs Friel and Walker, of Trinity College, Dublin, the artery to the upper lobe of the right lung is stated to lie directly behind the bronchus to that lobe in one instance, but it is not stated how the artery acquired this position, whether by passing superior or inferior to the bronchus.

Table III.—*Variations in the Arrangement of the Bronchi and Pulmonary Arteries on the Right Side. Total Number examined*, 130.




Explanation of Table:—

A, Artery, lower than bronchus.
B, Artery on same level with bronchus. } To upper lobe.
C, Artery above level of bronchus. } To upper lobe.
D, Dr Liddell's case (see text).

In an interesting case recorded by Mr F. G. Parsons, of St Thomas' Hospital, the horizontal fissure was *absent* from the *right* lung, but *present* in the *left*, the *right* lung having only *two* lobes, the *left three*. The eparterial bronchus was present on the right side, and was absent on the left.

In Mr Joseph Ganner's report from the Mason College, Birming-

ham, the following facts are recorded. In one case the bronchus divided into 3 branches—2 smaller ones to the upper lobe, and 1 larger one to the middle and inferior lobes. Of the two smaller branches, one is above the level of the upper division of the pulmonary artery, while the other is behind the artery. The lower branch is behind the lower branch of the pulmonary artery. In another case the bronchus gave off one larger eparterial branch to the upper and *middle* lobes, and 2 smaller hyparterial bronchi to the *lower lobe.*

In a carefully prepared return from Mr P. J. Fagan, of the Catholic University Medical School, he writes as follows:—

"In investigating this subject I adopted the following method. Having removed the right lung from the body, I injected the pulmonary artery with plaster, and then dissected out its chief branches as well as the larger subdivisions of the bronchus. I treated seven lungs in this way, with the following result.

"The right bronchus, after a course of about half an inch, gives off from its outer aspect a large horizontal branch, the sole supply of the upper lobe. About three-quarters of an inch lower down there arises from its anterior aspect a smaller branch for the middle lobe, and just beneath this a horizontal branch springs from the posterior aspect, which immediately distributes ascending, horizontal, and descending branches to the postero-lateral aspect of the upper region of the lower lobe. The next branch arises from the inner surface, and splits into two, for the postero-internal part of the lower lobe. Beneath and very close to this branch a large one is given off, from the anterior aspect, for the antero-lateral tract of the lower lobe. Then, close together, an anterior and a posterior branch. After this the branches are much reduced in size, one small one being given off from the anterior and two from the posterior aspect. Conjointly with the termination of the stem, these branches aerate the remainder of the lower lobe.

"The pulmonary artery lies in front of the main bronchus, below the level of the upper lobar, and just overlapping the origin of the middle lobar branch. It bifurcates, the upper division giving three branches to the upper lobe, which run on the inner side and in front of the corresponding branches of the upper lobar bronchus. The lower division, larger than the upper, winds outwards and slightly downwards until it gains a position between the upper and middle lobar bronchi. Here it distributes two branches, one upwards to the upper lobe, which runs behind the upper lobar bronchus, and is distributed behind and below it, and one to the middle lobe, which runs above and to the outer side of the middle lobar bronchus, its subdivisions preserving the same relation. Then the artery turns downwards and backwards, and runs on the postero-external aspect of the bronchus, gradually assuming the posterior position which it attains lower down. The branch corresponding to the horizontal bronchus mentioned above as springing from the posterior aspect of the main stem, arises near the bend of the artery. It is situated above and in front of its bronchus—in six above, and behind in one case. The arteries corresponding to the bronchi, named by Aeby "second ventral

and cardiac," are situated anteriorly and somewhat external to their bronchi in six cases, posteriorly and inferiorly in one case. Aeby's third ventral bronchus has its corresponding artery on its superior and anterior surface. The branch corresponding to the termination of the bronchus is behind."

Mr J. P. Hall, of The Owens College, Manchester, summarises his results in 6 cases in the subjoined diagram :—

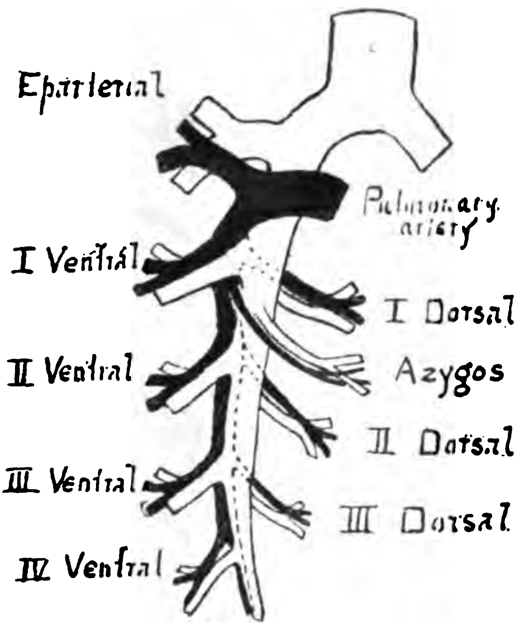



Diagram showing relations of right bronchus and its branches to the branches of the pulmonary artery.

## Question IV.

### The disposition of the spongy bones and meatuses of the nose, with especial reference to a fourth (highest) meatus.

The following answers have been received :—

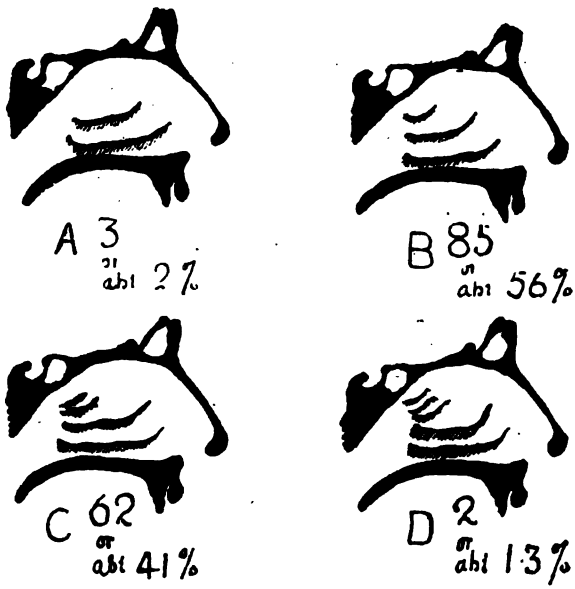
Messrs W. S. Haughton, Trinity College, Dublin ; Kieran Delany, Catholic University Medical School, Dublin ; R. A. Bennett, Mason College, Birmingham ; A. Eichholz, University of Cambridge ; Percy Flemming, University College, London ; F. G. Parsons, St Thomas' Hospital ; the University, Oxford ; J. R. Liddell, University of Edinburgh ; Mrs Flemming and Miss Bale, the London School of Medicine for Women.

152 observations have been made. The examination of each side

of the nasal fossæ is recorded as a separate observation. In some instances only one side has been examined, in others both sides have been inspected.

The results are shown in Table IV.

TABLE IV.—*Variation in the Number of Meatuses in the Nasal Fossæ. Total Number examined,* 152.




EXPLANATION OF PLATE :—

| | | | | |
|---|---|---|---|---|
| A, | Nasal Fossa, | with | 2 | Meatuses. |
| B, | ,, | ,, | 3 | ,, |
| C, | ,, | ,, | 4 | ,, |
| D, | ,, | ,, | 5 | ,, |

The condition figured at A is characterised by the absence of the superior turbinated bone, hence there are only two meatuses. Of this variety there are 3 instances recorded.

B represents the condition most commonly described, 85 examples of which are noted.

In C the existence of a *concha suprema* is represented coexistent with 4 meatuses. Sixty-two instances of this condition have been recorded.

In D is represented a condition in which 5 meatuses are described, the highest underlying a small projective lamella of bone, which is placed on a higher level than the *concha suprema*. Two instances of

this are recorded—one by Mr Liddell, of the University of Edinburgh, the other by Mr Eichholz, of Cambridge.

In connection with these varieties, Mr F. G. Parsons, of St Thomas' Hospital, states that in one of his cases, where the superior turbinated bone was absent, "there was a horizontal plate of cartilage projecting into the nasal fossa from the septum on a level with the inferior turbinated bone."

It may be as well to state here, that in the returns received the conditions on the two sides varied very much; but as the details given were in many instances meagre, no attempt has been made to tabulate the relative frequency of symmetry and asymmetry.

The relation of the various apertures of the air sinuses into the nasal fossa has been recorded by various observers, and Mr W. S. Haughton, of the School of Physic, Trinity College, Dublin, in an elaborate report, furnishes the subjoined table of results:—

## TABLE OF RESULTS.

*Apertures*:—

| | | |
|---|---|---|
| *Antrum of Highmore.*—ONE aperture occurred in . . . | 53 | per cent. |
| ,, ,, Two apertures ,, . . . . | 44·1 | ,, |
| ,, ,, THREE ,, ,, . . . . | 2·9 | ,, |
| *Antrum of Highmore* opening by *two* apertures *into the Infundibulum*, in . . . . . . . . . . | 17·6 | ,, |
| *Anterior Ethmoidal Cells*, opening by ONE aperture, just *above* middle of Infundibulum, in . . . . . | 76·4 | ,, |
| *Anterior Ethmoidal Cells*, by *one* aperture *into* Infundibulum, in | 8·8 | ,, |
| ,, ,, ,, by *two* ,, ,, ,, | 2·9 | ,, |
| ,, ,, ,, by *three* apertures (two of these opening into Superior Meatus, and one into Middle Meatus), in . . . . . . . | 5·8 | ,, |
| ,, ,, ,, by *one* aperture into a second gutter above Infundibulum, *common* to the Frontal Sinus as well . . . . . . . . . . | 5·8 | ,, |
| *Middle* and *Posterior Ethmoidal* Air Sinuses, *both* opening into the *Superior Meatus*, in . . . . . . . | 88·2 | ,, |
| *Middle Ethmoidal*, by *one* aperture into *Superior Meatus* . | 5·8 | ,, |
| ,, ,, ,, ,, *Middle* ,, . | 2·9 | ,, |
| ,, ,, ,, *two* ,, (one in a second gutter in the Middle Meatus, and one into Superior Meatus), in . | 2·9 | ,, |
| *Posterior Ethmoidal*, by *one* aperture into FOURTH MEATUS . . . . . . . . . . | 8·8 | ,, |
| *Middle and Posterior Ethmoidal*, by *one* into *Superior Meatus* | 75·3 | ,, |
| ,, ,, ,, ,, *two* ,, ,, | 11·7 | ,, |
| ,, ,, ,, ,, *three* ,, ,, | 5·8 | ,, |
| *Frontal Air Sinus*, by *one* aperture *into* Anterior end of Infundibulum, in | 94·1 | ,, |
| ,, ,, ,, by *one* ,, ,, a second gutter over Infundibulum . . . . . . . . | 5·9 | ,, |
| In *Crista Galli*, an Air Sinus, by *one*, in . . . . . | 2·9 | ,, |
| In *Middle Turbinated Bone*, an Air Sinus, by *one*, in . . | 2·9 | ,, |

Mr Parsons, of St Thomas', further adds that in one case the opening of the posterior ethmoidal cells lay in front of the superior turbinated bone. In one specimen with 3 meatuses, the antrum opened into the superior as well as into the middle meatus. In this case the opening of the posterior ethmoidal cells was above the superior turbinated bone.

In another case where the superior turbinated bone was represented by a mere ridge of mucous membrane, the antrum had two openings, one above and the other below the middle turbinated bone. The opening of the posterior ethmoidal cells lay anterior to the opening of the antrum in the superior meatus.

Mr Delany, of the Medical School, Catholic University, Dublin, notes that in 4 of his cases, with traces of a IV meatus, the posterior ethmoidal cells opened thereinto, and in 3 there was a foramen leading into the sphenoidal cells.

In presenting this their Fourth Annual Report, the Committee desire to thank the numerous gentlemen who have assisted them, and rendered it possible to carry on the work. They trust that many who have been unable to contribute this year will see it in their power to aid them in the next investigation.

The Secretary will be glad to receive any suggestions from members of the Society, and gentlemen who have recommendations to make regarding fresh inquiries are requested to communicate with him, addressed Department of Human Anatomy, Museum, Oxford.

# CASE OF LITHOPÆDION. By GEORGE DEAN, M.B., C.M., M.A., *Assistant to the Professor of Pathology in the University of Aberdeen, Assistant Pathologist to the Aberdeen Royal Infirmary*, and JOHN MARNOCH, M.B., C.M., M.A., *Assistant to the Professor of Physiology in the University of Aberdeen, Assistant Surgeon Aberdeen Royal Infirmary.*

**From the Pathological Laboratory, Aberdeen University.**

THE following case, from the extreme rarity of the condition, has seemed to us of sufficient interest to justify us in publishing it in some detail. At the outset we desire to express our thanks for permission to do so, to Dr Angus Fraser, in whose wards the case occurred.

Küchenmeister, in his elaborate paper[1] on the subject, gives a detailed account of all the cases of Lithopædion published between 1582 and 1881. He subdivides the cases that have been included under this designation into three great classes:—

1. Those with the fœtal membranes in a state of calcification.

2. Those with the membranes calcified and the fœtus calcified at the points adherent to the membranes.

3. Those in which the fœtus is calcified, the membranes being absent or forming a thin layer closely adherent to the fœtus.

This last is Lithopædion in the strict sense of the word.

Of the forty-nine cases described as such, and collected by him, twenty-three fall into the first division, three into the second, and eleven into the third. Of the remaining twelve cases, six were cases of maceration, two of saponification, and four were unclassified from insufficient data.

The present case falls into the third group, viz., that of true Lithopædion. In this class four of the cases have the same, or longer periods of gestation than the present, the longest being fifty-four years. One case belonging to the first subdivision reached a period of fifty-seven years, the woman dying at the age of eighty-eight. The subjoined case had a period of gestation of twenty-nine years.

[1] *Archiv für Gynaekologie*, 17.

*History of Case.*—Jessie Anderson, fifty-four years of age, was admitted to the Royal Infirmary, Aberdeen, on the 16th of November 1891, with the history of Chronic Bronchitis.

On examination she was found to be suffering from an acute attack, her dyspnœa being urgent, and the lividity of her lips, ears, face, &c., most marked. In the course of examination a tumour was discovered in the lower part of the abdomen in the right inguinal region. This tumour, on palpation, was rather larger than a child's head, was of very hard consistence, immovable and dull on percussion, the rest of the abdomen being resonant. It reached almost to Poupart's ligament and extended as far as the middle line, and to within 2½ inches of the umbilicus. From the history, which was of a somewhat scanty nature on account of patient's moribund condition, the tumour was diagnosed as a uterine myoma having undergone calcification. On inquiry at friends, however, the following facts were elicited regarding her:—

Twenty-nine years ago patient was delivered of a female child, labour being normal, and recovery good. Soon afterwards while at work in a linen manufactory, part of the building in which she was occupied fell, and in the panic that ensued, patient jumped down from one flat to another. As a result she became unconscious, and was taken to hospital, where she lay dangerously ill for some little time. From this illness, however, she recovered fairly well, but noticed that a small tumour began to be felt in the right side of her abdomen. This gradually grew in size, until it reached the dimensions mentioned above, but how long it took to do so, and what was the state of menstruation during its growth, could not accurately be made out. After that time patient enjoyed good health, the tumour causing her no inconvenience. There was no subsequent pregnancy, and menstruation continued regular until she was fifty years of age.

*Necropsy.*—On opening the abdominal cavity, the tumour above mentioned was felt to consist of two parts, a rounded mass the size of a cocoa-nut, and an irregularly shaped part with pointed projections. On closer examination it was found that the rounded mass was the head and the projections were the limbs of a fœtus. The whole was found to lie obliquely in the abdominal cavity, the head outwards, the lower extremities in the direction of the inlet of the pelvis. The occiput of the fœtus pointed towards the umbilicus. The head and extremities lay quite free in the abdominal cavity, without any attempt at encapsulation. The body had several adhesions, viz., to the small intestine and omentum above, to the fundus of the bladder below, and the posterior abdominal wall behind. The soft parts of the fœtus were seen to be in a state of calcification, a more detailed account of which will be given below.

The uterus was found to be in a state of senile involution. Protruding from the os uteri was what appeared to be the pedicle of a polypus. The ovary on the left side was absent, all that represented it being a small cyst the size of a pea. In the broad ligament near the fundus uteri on each side was a small nodule, in part calcareous. These two nodules occupied almost symmetrical positions. On microscopic examination they were found to be small hæmorrhages which had partly undergone calcification. The Fallopian tubes appeared normal.

*External Appearances.*—The head and neck were flexed, so that the face looked over the left shoulder. The features and external ears were indistinguishable, owing to their being covered by a calcareous plate continuous with the calcareous plate covering the rest of the fœtus. The soft coverings of the fontanelles were completely calcified. The various sutures of the cranium were very prominent, owing to overlapping of the cranial bones. The sagittal suture measured 2¾ inches, and the greatest circumference of the head was 10 inches. The spinous processes in the cervical region, owing to the flexed condition of the head, were very prominent.

*Trunk and Limbs:* The trunk was flexed antero-posteriorly, especially in the thoracic region, in which the spine had also a lateral curvature with the convexity towards the right. The limbs were flexed in the position natural to the child in utero. The left foot was hyper-extended, so that the dorsum of the foot lay in close contact with the front of the tibia. The balls of the toes and flexor tendons were well marked (as seen in the figure), the toes themselves being flexed so as to bring the nails into view. The right foot was found detached and lying adherent to the posterior wall of Douglas's pouch; here the proximal phalanges were in a condition of hyper-extension, the terminal ones were flexed, the whole condition resembling hammer-toe. The soft parts of the right knee-joint appeared to have undergone a process of disintegration, the articular cartilages being thus exposed. The left knee-joint appeared intact.

The right hand formed a gnarled mass, which lay adherent to the lower third of the flexor aspect of the forearm. The left hand was in a condition similar to the right.

The genitals and anus were completely obscured.

No trace could be found of the placenta and cord or its insertion.

Case of Lithopædion.

*Internal Anatomy.*—On removal of the skull-cap the diploe of the cranial bones was found infiltrated with a chalky deposit.

The brain itself retained to some extent its normal outline, but the fissures, with the exception of the longitudinal, were completely obscured. On removal, the brain matter had somewhat the colour and consistence of putty. The cranial nerves, with the exception of the optic, were entirely obliterated.

Both eyeballs remained practically intact, and on antero-posterior section showed the various parts, including the lens and choroid, to be little altered.

*Trunk:* In order to expose the internal anatomy of the trunk, the fœtus was frozen and an antero-posterior section made, dividing the body into two almost equal parts. This section demonstrated the fact that the spinal column had been subjected to considerable longitudinal pressure, partial dislocation having occurred at one or two points.

The naked-eye appearances of the viscera were found to be almost unchanged, except for the fact that they had a somewhat bleached appearance, and that here and there calcification was observed to have occurred.

In the thoracic region the lungs, with their various lobes, were clearly made out. No distinct law seemed to govern calcification, which had taken place in the form of isolated nodules of sizes varying from a pin-head to a split-pea. The cardiac muscles seemed almost free from calcification, but on opening the right ventricle a small cretaceous particle was found in its interior, evidently calcified blood-clot. The musculi papillares were easily distinguishable.

The aorta, from the point where it leaves the heart to the diaphragmatic opening, was in excellent preservation, the lumen of the vessel being patent. The pulmonary artery was clearly visible.

The tendinous and muscular parts of the diaphragm were distinct.

In the abdomen the coils of the intestine and the liver were the most prominent objects. The alimentary tract and the mesentery, with its vessels, were beautifully preserved. The liver, the anterior edge of which was tilted upwards from the pressure, had to a considerable extent its chocolate-brown colour.

One kidney was divided by the section, and the ureter could be easily found.

Calcification had occurred to a large extent in the pelvis, so that the viscera with the genital organs could not be discovered.

*Microscopic Anatomy.*—*Surface:* On making a section vertical to the surface the following structures were seen from without inwards :—

1. A number of laminæ of connective tissue-like structure, evidently the membranes. 2. The flattened lanugo, some of the hairs cut longitudinally, others transversely. Only here and there, however, could traces of the epidermis be discovered. 3. The derma and underlying structures.

*Brain:* The putty-like material representing the brain was found to consist of an amorphous granular material, through which were scattered numerous cholesterin and margarine crystals.

*Lungs:* The pleura was unaltered, while, on the contrary, the lung substance, although presenting the general appearances of fœtal lung, was scarcely so well preserved. A section through the root showed the cartilages of the bronchi, but the mucous membrane was disintegrated.

*Heart:* On teasing some of the cardiac muscle, the striation of the fibres was sharply defined. The nuclei, however, could not well be made out.

*Diaphragmatic Muscle:* This tissue differed little, if at all, from fresh muscular fibre.

*Liver:* The polyhedral cells of this gland were well defined.

*Kidney:* The glomeruli and tubules were easily recognisable, some parts showing with great distinctness, especially the epithelium of the straight tubes of the medulla.

*Stomach and Intestine:* Here the serous and muscular coats were entire, but the mucous membrane had undergone disintegration and was represented by some granular debris.

The above case opens up many interesting problems in connection with the question of extra-uterine pregnancy.

Most extra-uterine pregnancies are now held to be first tubal in site, and the history points to the accident being, in this case, the cause of rupture.

Such being the case, the task of explaining the development

of the ovum within the abdominal cavity becomes, in the light of recent views, not a difficult one. From being tubal, it became an intra-abdominal pregnancy, and in such cases the placenta may attach itself to any abdominal structure, such as the omentum, as in the case recorded by Maticki,[1] and thus the development of the fœtus continues. In the present instance, however, all trace of the placenta and its attachments had disappeared. The fact that the left ovary was absent is not of much significance, inasmuch as the ovary is frequently absent in cases which are undoubtedly tubal.[2]

Another problem of great interest is that of the conversion of the fœtus into the condition of Lithopædion. The reason why disintegration occurred in parts of the limbs such as the knee-joint, while the head and trunk remained intact, was in all probability due to the relation the membranes had to these parts. Extrusion of the extremities had taken place through the membranes, which, however, became closely applied to the rest of the fœtus.

The law governing the uniform calcification of the superficial structures seems to us to be explicable on the same lines as the calcification found in infarcts. In both cases the tissues first undergo coagulative necrosis, and then there sets in the deposition of insoluble lime salts. Just as in Litten's experiments on the kidney,[3] so the permeation of the superficial necrosed structures of the fœtus by the lymph of the mother was followed by their calcification. This therefore acting as a protective covering for the internal anatomy, accounts for the excellent preservation of the viscera, and also for the imperfect and irregular calcification found in them.

In connection with the above paper, we desire to express our thanks to Professor Hamilton for advice and the use of the necessary apparatus for conducting the examination of the specimen.

[1] *Vide Diseases of Women and Abdominal Surgery*, Tait, vol. i. p. 450.
[2] Tait, *loc. cit.*, p. 445.
[3] *Virchow's Archiv*, 83, p. 508.

# THE ORIGIN AND DISTRIBUTION OF THE NERVES TO THE LOWER LIMB.[1] By A. M. PATERSON, M.D.,

*Professor of Anatomy in University College, Dundee.*

## INTRODUCTION.

THE following investigation was begun several years ago, with the object of testing the validity of the rules laid down by Herringham (1) for the upper limb, in relation to the distribution of the nerves of the lumbo-sacral plexus to the lower limb; of clearing up certain doubtful points in the anatomy of the plexus and its relations to the vertebral segments; and of defining, if possible, the exact area of distribution in the lower limb of the several spinal nerves entering into the composition of the plexus.

While the work has been in progress,—and, for various reasons, it has been laid aside from time to time, and has only been continued as circumstances permitted,—several important memoirs have appeared, dealing with different aspects of the subject. These have been of the greatest assistance to me in formulating conclusions, confirming observations, and throwing light upon certain obscure points. Ross (2), Thorburn (3), Starr (4), M'Kenzie (5), and Head (6) have attacked the subject from the clinical standpoint; Eisler (7) has made exhaustive investigations into the anatomy of the plexus, and certain of the branches emanating from it; and Sherrington (8) has made valuable observations on an experimental basis into the distribution of the motor and sensory roots of the spinal nerves supplying the lower limb.

To separate individual nerve trunks into their component elements, and to trace to their peripheral terminations the various subdivisions of the constituent spinal nerves, is now recognised as a feasible operation. It must, at the same time, be conceded that the process is difficult and laborious, especially in the case of the smaller nerves of the limb, which may have

[1] Read in the Section of Anatomy and Physiology, at the Meeting of the British Medical Association in Newcastle, 1893.

an origin from more than one spinal trunk, and a lengthy course to their termination. I would, therefore, at the outset guard myself against any apparent dogmatism in the statements made below regarding the precise spinal origin of particular nerves. The difficulty one has in following out fine nerves in their whole length, and often for so considerable a distance; the small number of cases reported on (although these are, in the main, by their mutual agreement, confirmatory of the accuracy of the process); and the undoubted existence of individual variations (within certain limits), are factors which combine to make one's results less definite, and which lead me to offer my conclusions with a certain amount of diffidence.

*Individual variability* in the composition of the plexus and in the origin of the nerves of distribution is clearly illustrated below. It has also been noticed by Sir W. Turner (7*) in relation to both the upper and lower limbs, by Herringham (1) in relation to the upper limb, and by Eisler (7) and Sherrington (8) in relation to the lower limb. Eisler has paid particular attention to the thickness and amount of different spinal nerves entering into the formation of individual branches in the lumbo-sacral plexus. He records at least three varieties from the normal arrangement, in which the plexus formation is more proximally or more distally placed than usual in relation to the spinal-cord; but he shows at the same time the undoubted correlation which in all cases subsists among the nerves derived from the plexus. Sherrington designates as "prefixed" and "postfixed" two separate types of lumbo-sacral plexus, according to its position in relation to the long axis of the body and the limb. (The similar individual variability which, as is well known, the lower limb itself possesses in relation to the vertebral axis, will be referred to again; it is not certain whether the two variations are correlated, or only coincident.)

In the prosecution of this investigation, I have been indebted to various friends, who have undertaken parts or the whole of the dissection of different cases. The notes of each dissection were taken separately, and independently of previous results; and there was often a considerable interval between the dissection of one case and the next. The dissection was greatly facilitated by the use of a 5–10 per cent. solution of nitric

acid, with which the nerve trunks were soaked. While this has a very deleterious effect upon knives and forceps, it is of the greatest aid in the separation of the nerve bundles into their ultimate elements, by dissolving the connective tissue, and at the same time hardening the nerves themselves. The mode of operation found most satisfactory was first to clean thoroughly the anterior primary divisions of the spinal nerves composing the plexus, and to trace them as far as possible through the plexus as independent, separate bundles; thereafter the nerves of distribution were isolated, and followed up from their peripheral terminations to the plexus, the individual cutaneous and muscular branches being separated in the process.

*The method of determining results* requires a word of explanation. It was often found impossible to trace back with precision to its origin a fine nerve which appeared to arise from more than one spinal root: in the notes made at the time, I therefore made it a rule rather to err on the side of indefiniteness, and to include among the spinal nerves comprising a given branch, roots which might really not belong to it, rather than risk the destruction of a root which might possibly be essential. One ran less risk of error by associating in the origin of a given nerve contiguous roots, than by the endeavour to be accurate and the possible destruction of essential roots. In other words, the attempt was not made to be absolutely definite in mapping out the exact areas in the limb supplied by each individual spinal nerve. It is doubtful whether it is possible by anatomical methods to arrive at such a precise conclusion. It is well known that in the case of the cutaneous nerves to the limbs there is considerable overlapping in the distribution of the nerves to a given area (9); and it appears certain from Sherrington's observations (8 *b*) that no spot in the skin is supplied by one spinal nerve alone. (It seems also to be more than doubtful, from Sherrington's observations and my own, whether any muscle in the limb is supplied by one spinal nerve alone.)

On comparing together the results of my dissections, I found that in the formation of a given nerve, more or fewer spinal nerves are implicated in different cases. For example, in the subjoined Table of Details, in group D, the small sciatic nerve was dissected out six times: in five cases it arose from S.2.3;

and in one case from S.1.2.3. In striking an average, the origin of the nerve is described as S.(1).2.3. In compiling averages for the whole series, only those roots of a given nerve are entered as essential which are found in at least half the cases. The roots occurring in a minority of cases, and those entered in brackets, are omitted, as either doubtful or only occasional roots. This has seemed to me the best way of arriving at the result desired,—the "normal" condition. The accompanying table (Table I.) gives at the same time the averages for the dissection of the various groups into which the cases have been subdivided.

## Description and Analysis of Dissections.

I. *Composition of the Lumbo-sacral Plexus, and Origin of its Branches.*—The total number of dissections made was 23, comprising both sides of 8 adults and one child (18), and 5 other cases dissected on one side only (4 adult and 1 child).

The external and internal popliteal nerves were naturally separated in three cases (13 per cent.) by a slip of the pyriformis muscle. This is a smaller number than Eisler found: out of 127 plexuses, he obtained 23 cases of a natural separation of these nerves, or 18·1 per cent. Sir W. Turner also states (7*) that it is not uncommon to find the great sciatic nerve divided into two roots of origin.

In the accompanying Table of Details (Table I.), the subjects examined are arranged according to the constitution of the plexus. A broad separation of the plexuses may be made into two main types, distinguished by the position of the *n. furcalis*. This distinction is a familiar one, owing to the investigations of von Jhering (10). In nineteen cases the *n. furcalis* was furnished by the fourth lumbar nerve, and in four cases by the fifth lumbar. We may regard the first type as normal or prefixed, the second as abnormal or postfixed.

The first or normal type may be further subdivided into four groups (A. B. C. D.) according to the position of the caudal termination of the roots of the popliteal nerves. In this respect there is considerable variability. Group A. represents the most prefixed variety. It contains seven examples, in which the

# TABLE I.

*Details of the Origins of the Muscular and Cutaneous Nerves derived from the Lumbo-sacral Plexus.*

| NERVES. | Group A. Average of Seven Cases. | Group B. Average of Three Cases. | Group C. Average of Three Cases. | Group D. Average of Six Cases. | Total Average for Nineteen Normal Cases. | Group E a. Average of Three Cases. | Group E b. One Case. | Total Average for Four Abnormal Cases. |
|---|---|---|---|---|---|---|---|---|
| Twelfth thoracic, | present once. | .. | present twice. | .. | present three times. | present once. | present. | present twice. |
| Ilio-hypogastric | (12)·1 | 1 | 12·1 | 1 | (12)·1 | (12)·1 | 12·1 | 12·1 |
| Ilio-inguinal | (12)·1 | 1 | (12)·1 | 1 | (12)·1 | (12)·1 | 12·1 | 12·1 |
| Genito-crural | (12)·1·2 | 1·2 | 1·2 | 1·2 | (12)·1·2 | 1·2 | 2 | 1·2 |
| Genital | (12)·1·2 | 1·2 | 1·(2) | 1·2 | (12)·1·2 | (1)·2 | 2 | (1)·2 |
| Crural | 1·2 | 1·2 | 1·2 | 1·2 | 1·2 | (1)·2 | 2 | (1)·2 |
| External cutaneous | 1·2·(3) | (1)·2·(3) | 1·2·3 | 2·3 | 1·2·3 | 2·3 | 2 | 2·3 |
| anterior | (1)·2·(3) | 2 | 1·2·3 | 2·3 | (1)·2·3 | 2·3 | 2 | 2·3 |
| posterior | 1·2·(3) | 2·3 | 1·2·3 | 2·(3) | 1·2·3 | 2·3 | 2 | 2·3 |
| Obturator | 2·3·4 | 2·3·4 | 2·3·4 | 2·3·4 | 2·3·4 | 3·4·(5) | 3·4·5 | 3·4·5 |
| Pectineus | .. | .. | (3·4) (1 case) | .. | .. | .. | .. | .. |
| Adductor longus | 2·3·(4) | 2·3 | 2·3 | 2·3·4 | 2·3·(4) | 3·(4) | 3·4 | 3·4 |
| Gracilis | 2·3·(4) | 2·3·(4) | 2·3·4 | 2·3·4 | 2·3·4 | 3·4 | 3·4·5 | 3·4·5 |
| Obt. plexus | .. | (2)·3·(4) | 3·4 | 2·3·4 | (2)·3·4 | 3·4 | 3·4 | 3·4 |
| Cutaneous | 2·3·(4) | (2)·3·(4) | 2·3·4 | (2)·3·4 | 2·3·4 | 3·4 | 3·4 | 3·4 |
| Fem. artery | 2·3 | 2·3 | 1·2·3 | 2·3 | (1)·2·3 | .. | 3 | 3 |
| Add. magnus | 2·3·4 | (2)·3·4 | (2)·3·4 | (2)·3·4 | (2)·3·4 | 3·4·(5) | 3·4·5 | 3·4·5 |
| Knee-joint | (2)·3·4 | 3·4 | (2)·3·4 | (2)·3·4 | (2)·3·4 | 3·4·(5) | 3·4·5 | 3·4·5 |
| Obt. externus | (2)·3·4 | 3·4 | 3·4 | (2)·3·4 | (2)·3·4 | (3)·4·(5) | 5 | (3)·4·5 |
| Add. brevis | 2·3 | 2·3·(4) | (2)·3·4 | 2·3·4 | 2·3·4 | 3·4 | 3·4·5 | 3·4·5 |
| Anterior crural | 1·2·3·4 | 2·3·4 | (1)·2·3·4 | 2·3·4 | (1)·2·3·4 | 2·3·4·5 | 2·3·4·5 | 2·3·4·5 |
| Middle cutaneous | (1)·2·3 | 2·3·(4) | (1)·2·3 | 2·3 | (1)·2·3·(4) | 2·3 | 2·3 | 2·3 |
| external | 1·2·(3) | 2·3·(4) | (1)·2·(3) | 2·3 | (1)·2·3·(4) | 2·3 | 2·3 | 2·3 |
| internal | 2·(3) | 2·3·(4) | (1)·2·3 | 2·3 | (1)·2·3·(4) | (2)·3 | 2·3 | 2·3 |
| Internal cutaneous | 2·3 | 2·3·(4) | 2·3 | 2·3 | 2·3·(4) | 2·3·4 | 2·3 | 2·3·4 |
| anterior | 2·3 | 2·3·(4) | 2·3 | 2·3 | 2·3·(4) | 2·3 | 2·3 | 2·3 |
| internal | 2·3 | 2·3·(4) | 2·3 | 2·3 | 2·3·(4) | (2)·3·4 | 2·3 | 2·3·4 |
| Internal saphenous | 2·3·4 | (2)·3·4 | 2·3·4 | 2·3·4 | 2·3·4 | 3·4 | 3·4 | 3·4 |
| Patellar br. | 2·3·(4) | (2)·3·4 | (2)·3·(4) | (2)·3·4 | (2)·3·4 | 3·4 | 3·4 | 3·4 |
| below knee | 2·3·4 | 3·4 | (2)·3·4 | 3·4 | (2)·3·4 | 3·4 | 3·4 | 3·4 |
| Sartorius | 2·3·(4) | 2·3·(4) | (1)·2·3·(4) | 2·3 | (1)·2·3·(4) | (2)·3·4 | 3 | (2)·3·4 |
| Pectineus | 2·3 | 2·3 | (1)·2 | 2·3 | 2·3 | 2·3·(4) | 2·3·4 | 2·3·4 |
| Vast. internus | (2)·3·4 | (2)·3·4 | 3·4 | 3·4 | (2)·3·4 | 3·4·5 | 3·4·5 | 3·4·5 |
| Crureus | 3·4 | (2)·3·4 | 3·4 | 3·4 | (2)·3·4 | 4·5 | 4·5 | 4·5 |
| Rectus fem. | (2)·3·4 | 2·3·4 | 3·4 | (2)·3·4 | (2)·3·4 | (3)·4·5 | 3·4 | 3·4·5 |
| Vastus externus | 3·4 | (2)·3·4 | 3·4 | (2)·3·4 | (2)·3·4 | (3)·4·(5) | 4·5 | (3)·4·5 |
| Psoas | (1)·2·3·(4) | 2·3·4 | 1·2·3·4 | (1)·2·3·(4) | (1)·2·3·4 | 2·3 | 3·4·5 | 2·3·4·5 |
| Iliacus | (2)·3·4 | 2·3·4 | 2·3·4 | 3·4 | 2·3·4 | 3·4·5 | 1·2·3·4 | 1·2·3·4·5 |
| Superior gluteal | 4·5·1·(2) | 4·5·1 | 4·5·1 | 4·5·1 | 4·5·1·(2) | 5·1·2 | 5·5·1 | =5·1·2 |
| G. medius | 4·5·1·2 | .. | .. | .. | 4·5·1·2 | 5·1·2 | .. | 5·1·2 |
| G. min. and Tens. fasc. fem. | 4·5·1 | .. | .. | .. | 4·5·1 | 5·1 | | [illegible] |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Inferior gluteal | 5·1·2 | 5·1·2 | 5·1·2 | 5·1·2(3) | 5·1·2(3) | 5·1·2 | 6·1 | 5·1·2 |
| Small sciatic | 1·2(3) | 1·2·3 | 1·2·3 | (1)·2·3 | 1·2·3 | 2·3 | 1·2 | 1·2·3 |
| Buttock | 1·2(3) | 1·2·3 | 1·2·3 | (1)·2·3 | 1·2·3 | 2·3 | 1·2 | 1·2·3 |
| Thigh | 1·2 | 1·2·3 | 1·2·3 | (1)·2·3 | 1·2·3 | 2·3 | 1·2 | 1·2·3 |
| Perinæum | (1)·2(3) | 2·3 | (1)·2·3 | 2·3 | (1)·2·3 | (2)·3 | 1·2 | 1·2·3 |
| Pudic | 2·3·4 | 2·3·4 | 2·3·4 | (2)·3·4 | 2·3·4 | 3·4 | 2·3 | 2·3·4 |
| Inf. hæmorrhoidal | (2)·3·4 | 3·4 | 2·3·4 | 3·4 | (2)·3·4 | 3·4 | 2·3 | 2·3·4 |
| Perinæum | 2·3(4) | 2·3 | 2·3 | 3(4) | 2·3(4) | 3·4 | 2·3 | 2·3·4 |
| Penis | 2·3(4) | 2·3 | 2·3 | 3(4) | 2·3(4) | 3 | 2·3 | 2·3 |
| Pyriformis | 1·2 | 2 | 1·2 | (1)·2 | 1·2 | 2 | 2 | 2 |
| Obt. internus and sup. Gemell. | (4)·5·1·2(3) | (5·1)·2 | (5)·1·2·3 | (5)·1·2·3 | (4·5)·1·2·3 | 1·2·3 | .. | 1·2·3 |
| Quad. Fem. and inf. Gemell. | 4·5(1) | 4·5·1 | 4·5·1 | 4·5(1) | 4·5·1 | 5·1 | .. | 5·1 |
| External popliteal | 4·5·1 | 4·5·1·2 | 4·5·1 | 4·5·1·2 | 4·5·1·2 | 5·1·2 | 5·6·1(2) | 5·1·2(3) |
| Biceps (short head) | (4)·5·1 | 1·2 | 5·1 | (4·5)·1·2 | (4)·5·1·2 | (5)·1·2 | 6·1 | (5) 1·2 |
| Knee-joint | 4·5(1) | 1·2 | 4·5·1 | 4·5 | 4·5·1(2) | 5(1·2) | 6 | 5·1(2) |
| Com. fibularis | (4)·5·1 | 1·2 | 5·1 | (5)·1·2 | (4)·5·1·2 | (5)·1·2 | 5·6·1(2) | 5·1·2 (3) |
| Anterior tibial | 4·5(1) | 4·5·1 | 4·5·1 | 4·5·1 | 4·5·1 | 5·1·2 | 5·6 | 5·1·2 |
| muscles of leg | 4·5(1) | 4·5·1 | 4·5·1 | 4·5·1 | 4·5·1 | 5·1·2 | 5·6 | 5·1·2 |
| muscle of foot | 4·5(1) | (4)·5·1 | 4·5·1 | 4·5·1 | 4·5·1 | 5·1(2) | 5·6 | 5·1(2) |
| cutaneous | 4·5(1) | 4·5·1 | 4·5·1 | (4)·5·1 | 4·5·1 | 5·1(2) | 5·6 | 5·1(2) |
| Recurrent tibial | 4·5·1 | 4·5 | 4·5·1 | 4·5·1 | 4·5·1 | 5·1(2) | 5·6 | 5·1(2) |
| Musculo-cutaneous | 4·5·1 | 5·1 | 5·1 | 4·5·1·2 | 4·5·1(2) | 5·1·2 | 6·1 | 5·1·2 |
| Peronei | 4·5·1 | 5·1 | 5·1 | 4·5·1 | 4·5·1 | 5·1·2 | 6·1 | 5·1·2 |
| cutaneous | 4·5·1 | 5·1 | 5·1 | 4·5·1·2 | 4·5·1(2) | 5·1(2) | 6·1 | 5·1·2 |
| Internal popliteal | 4·5·1·2 | 4·5·1·2 | 4·5·1·2·3 | 4·5·1·2·3 | 4·5·1·2·3 | 5·1·2·3 | 5·6·1·2 | 5·1·2·3 |
| Ext. saphenous | 1(2) | 1·2 | (1)·2(3) | (1)·2(3) | 1·2(3) | 2·3 | 1·2 | 1·2·3 |
| Biceps (long head) | (5)·1·2 | (5·1)·2 | (4·5)·1·2·3 | (5·1)·2·3 | (5)·1·2·3 | (1)·2·3 | 6·1·2 | 1·2·3 |
| Semi-tendinosus | (4)·5·1·2 | 5·1·2 | (4)·5·1·2(3) | (5)·1·2(3) | (4)·5·1·2(3) | 5·1·2(3) | 5 | 5·1·2(3) |
| Semi-membranosus | 4·5·1(2) | 4·5·1 | 4·5·1(2·3) | 4·5 | 4·5·1(2·3) | 5(1·2) | 5·6 | 5·1(2) |
| Adductor magnus | 4·5(1) | 4·5·1 | 4·5(1·2·3) | 4·5·1 | 4·5·1(2·3) | 5 | 5 | 5 |
| Knee-joint | 4·5 | 4·5·1 | 4·5 | 4·5·1 | 4·5·1 | 5·1 | 5·6 | 5·1 |
| Gastrocnemius | (5)·1·2 | (5)·1·2 | (5)·1·2(3) | (1)·2·3 | (5)·1·2(3) | 1·2(3) | 1·2 | 1·2·3 |
| outer head | (5)·1·2 | (5)·1·2 | (5)·1·2(3) | (1)·2·3 | (5)·1·2(3) | 1·2 | 1·2 | 1·2·3 |
| inner head | 1·2 | (5·1)·2 | 1·2(3) | 2·3 | (5)·1·2(3) | (1)·2(3) | 1·2 | (1)·2·3 |
| Soleus | 5·1(2) | (5)·1·2 | (5)·1·2(3) | 1·2 | (5)·1·2(3) | 1·2 | 1·2 | 1·2·3 |
| Plantaris | 4·5(1·2) | (4)·5·1 | 4·5 | 1 | 4·5·1(2) | 5·1 | 6 | 5·1 |
| Popliteus | (4)·5(1) | 5·1·2 | 4·5·1 | 4·5(1·2·3) | 4·5·1(2·3) | 5·1 | 5·6 | 5·1 |
| Posterior Tibial | 4·5·1·2 | 4·5·1·2 | (4)·5·1·2(3) | (4)·5·1·2·3 | 4·5·1·2(3) | 5·1·2·3 | 5·6·1·2 | 5·1·2·3 |
| Soleus | 5·1(2) | 5·1·2 | 5·1·2 | (5)·1(2) | 5·1·2 | (5)·1(2) | 6·1 | (5)·1·2 |
| Tibialis posticus | 4·5(1) | 5·1(2) | (4)·5·1(2) | (4)·5·1 | (4)·5·1(2) | 5·1 | 5 | 5·1 |
| Flexor long. dig. | (4)·5(1) | 5·1(2) | (4)·5·1(2) | (5)·1(2) | (4)·5·1(2) | 5·1 | 5 | 5·1 |
| Flexor long. hall. | (4)·5·1 | 5·1(2) | (4 5)·1·2 | 1·2(3) | (4)·5·1·2(3) | (5)·1(2) | 6·1 | (5)·1·2 |
| Calcanean br. | (4·5)·1·2 | (5)·1·2 | 1·2(3) | 1·2·3 | (4·5)·1·2(3) | 5·1·2·3 | 1·2 | 5·1·2·3 |
| External Plantar | 5·1·2 | 4·5·1·2 | (5)·1·2(3) | (5)·1·2·3 | (4)·5·1·2(3) | (5)·1·2·3 | 1·2 | (5)·1·2·3 |
| muscular | 5·1(2) | 1·2 | (5)·1·2 | (5)·1·2·3 | (5)·1·2(3) | (5)·1·2(3) | 1·2 | (5)·1·2·3 |
| *cutaneous (6) | (5)·1(2) | 1·2 | 1·2(3) | (1)·2·3 | (5)·1·2(3) | 2·3 | 1·2 | 2·3 |
| " (5) | 5·1(2) | 1·2 | 1·2 | (5)·1·2·3 | (5)·1·2(3) | 1·2 | 1 | 1·2 |
| Internal Plantar | 4·5·1(2) | 4·5·1·2 | 4·5·1·2 | 4·5·1·2 | 4·5·1·2 | 5·1(2) | 5·6·1·2 | 5·1·2(3) |
| muscular | 4·5(1·2) | 4·5 | 4·5(1) | 4·5·1(2) | 4·5(1·2) | 5·1(2) | 5·6 | 5·1(2) |
| cutaneous (4) | 5·1(2) | 5·1 | 5·1·2 | 5·1(2) | 5·1(2) | 1(2) | 6·1·2 | 1·2(3) |
| " (3) | (4)·5·1(2) | 5·1 | 5·1 | 5·1 | (4)·5·1(2) | 5·1(2) | 6·1 | 5·1·2 |
| " (2) | (4)·5·1 | 4·5·1 | 4·5·1 | (4) 5·1(2) | 4·5·1(2) | 5·1 | 5·6 | 5·1 |
| " (1) | 4·5(1) | 4·5 | 4·5 | 4·5(1·2) | 4·5(1·2) | 5(1) | 5·6 | 5·1 |

[1] The numerals 6–1 refer to the branches to the toes from the outer to the inner side of the foot in order.

external popliteal nerve arises from L.4.5.S.1; the internal popliteal nerve from L.4.5.S.1.2. In one case the 12th thoracic nerve entered into the formation of the lumbar plexus; and in four out of the seven cases the 1st lumbar nerve was the first root of the anterior crural nerve. There are further indications of other nerves of distribution having a more proximal origin than usual from the plexus (*e.g.*, *v.* Table I., small sciatic, S.1.2.(3); external saphenous, S.1.(2); n. to soleus, L.5.S.1.(2), &c.). In the second and third groups (B. and C.) the plexus shows indications of occupying a slightly more postaxial position. In each group there are three examples. In group B. both external and internal popliteal nerves arise from the same spinal trunks—L.4.5.S.1.2. In group C., the peroneal nerve arises from L.4.5.S.1, while the tibial nerve, taking up a more distal root, arises from L.4.5.S.1.2.3. The fourth group (D.) represents the most postfixed variety of this type. It contains six examples, in which both popliteal trunks have increased the number of their roots by extension distally; the peroneal nerve arising from L.4.5.S.1.2, the tibial nerve from L.4.5.S.1.2.3.

It is important to notice the proximal and distal limits of the plexus in this normal type. Out of 19 cases, the proximal limit was the 1st lumbar nerve in 12 cases, the 12th thoracic in 3 cases (in four cases it was not noted). If the small sciatic nerve is excluded in determining the distal limit, it is formed by S.2 in 10 cases, by S.3 in 9 cases. Including the small sciatic, S.2 becomes the distal limit in 5 cases (all of the first or most prefixed variety (A.)), while S.3 is the limit in 14 cases.

The second type of plexus (abnormal or postfixed) is distinguished from the first by the fact that the 5th instead of the 4th lumbar nerve forms the *n. furcalis*. Along with this the various branches emanating from the plexus (and correlated one with another) show a tendency to arise from spinal nerves derived from a more caudal portion of the spinal cord. This type includes four cases, in three of which the peroneal nerve arises from L.5.S.1.2; the tibial nerve from L.5.S.1.2.3. In a fourth case the backward location of the *n. furcalis* is accompanied by a concomitant caudal retrogression of the attachment of the ilium to the sacrum on one side, giving rise to six lumbar vertebræ, and altering consequently the designation of

the spinal nerves. The peroneal nerve arises from L.5.6.S.1; the tibial nerve from L.5.6.S.1.2. This case occurred in a negro, and is referred to elsewhere (11, 12). On the other side of the same subject the arrangement of the nerves was identical, and the plexus is included among the three previous cases under this type; but the attachment of the ilium to the sacrum was normal (*i.e.*, to the 25th instead of the 26th vertebral segment).

Among these four abnormal cases, in which the *n. furcalis* was furnished by L.5, the proximal limit of the plexus was in two cases the 12th thoracic, and in two cases the 1st lumbar nerve. In all cases the anterior crural nerve was formed by L.2–5. And in all cases the distal limit of the plexus was formed by S.3, whether the small sciatic nerve is included or excluded. Eisler, from an examination of 127 plexuses, concludes that the normal condition is a plexus with L.4 as *n. furcalis*, a distal limit formed by S.3, and popliteal nerves derived from L.4.5.S.1.2 and L.4.5.S.1.2.3. He records 22 abnormal cases, which are extremely interesting. In three of them L.5 is *n. furcalis;* in two others, L.5 is *n. furcalis*, and there is in addition a loop between L.4 and L.5; in fourteen cases there is a decussation between L.4 and L.5, so that both nerves contribute to both lumbar and sacral portions of the plexus; in one case L.4 is *n. furcalis*, and at the same time a loop exists between L.3 and L.4; and lastly, in two cases there is a decussation between L.3 and L.4, so that fibres from both pass to both lumbar and sacral portions of the plexus. These abnormal cases exhibit a number of slight degrees of variation in the position of the plexus, and indicate that the shifting of the plexus proximally or distally is not due of necessity to the omission or inclusion of a whole spinal root, but is accompanied by an altered relation, it may be, of only a few (contiguous) fibres emanating from the spinal cord. None of my cases exhibited the loops of connection or the transitional stages represented by a double *n. furcalis;* but it will be remarked that among them there is a far larger proportion of examples of plexuses in which L.5 is *n. furcalis* than in Eisler's cases.

Both Eisler's results and my own show clearly the direction in which the variations from the normal condition of the plexus usually extends. Assuming that the position of the *n. furcalis*

at the 4th lumbar nerve is the normal one, it is obviously, from the above analysis, much more common for the plexus formation to be shifted backwards, in a caudal direction, than forwards, towards the head end of the body. All my cases of variation are indicative of a caudal shifting; and of Eisler's exceptional cases, 19 are examples of shifting of the plexus in a caudal direction, 3 in a cephalic direction. This has an interesting bearing upon Rosenberg's hypothesis (19) regarding the alteration of the position of the limb. It shows that the evidence of the nervous system gives no support to his hypothesis; but bears out the view of an individual variability in the position of structures related to the limb, with rather a tendency to an extension in the caudal direction than the reverse, rather an amplification than restriction of the longitudinal extent of the trunk above the lower limb.

With regard to the variability of the nervous and osseous elements of the lower limb, it is a matter for regret that Eisler has not recorded the condition of the spinal column and the relation of the sacro-iliac articulation in his cases. I have given reasons elsewhere (12) for the opinion that the position of the limb itself, and the arrangement of the lumbo-sacral plexus in relation to the vertebral segments, are not to be regarded as inseparably connected together. I have shown that the osseous or nervous conditions may vary separately or together. It has been already stated above, that in only one of the cases under discussion was there a variation in the relation of the lower limb to the spine, and a concomitant alteration of the position of the *n. furcalis*, and a consequent shifting (posteriorly) of the nerves of the plexus. This case is an example indicating that the two conditions may be correlated; but more information is still required before one can come to any definite or final conclusion on this point.

The examination of these records indicates, moreover, that while there is distinct individual variability, and, as both Eisler and Sherrington have observed, a tendency for the plexus formation to be shifted proximally or distally, yet the limits within which this variability is expressed are very narrow. The plexus is always included between the 12th thoracic and the 3rd sacral nerves, and ordinarily between the 1st lumbar and 3rd sacral

nerves. Further, it is not always the plexus which extends furthest in a caudal direction which recedes furthest from the proximal limit. In two out of four cases in which the *n. furcalis* is formed by L.5, and the distal limit of the plexus is S.3, the 12th thoracic nerve forms the proximal limit of the plexus. Again, in the normal type, and in the most prefixed variety (group A. in the table), while the 2nd sacral nerve forms the distal limit of the plexus in 5 cases out of 7 (including in the plexus the small sciatic nerve), the 12th thoracic nerve is only once implicated. These points—(1) the narrow limits within which the variations in the composition and location of the lumbo-sacral plexus occur, and (2) the fact that the variations are not strictly speaking segmental, that is, do not imply a shifting of a whole segment, but, it may be, only a small part of one—appear to me to indicate (1) a tendency as much towards variability in the length of the area of the spinal cord involved in the composition of the plexus, in the restriction or amplification in the area of outflow of the spinal nerves from the spinal cord to the limb, as towards a definite shifting of the limb plexus, either in a cephalic or caudal direction, and (2) that the segmentation of the spinal nerve roots possesses mainly a morphological significance, and from the point of view of the composition of the plexus, and the innervation of the limb is not of primary importance.

Regarding the constitution of the lumbo-sacral plexus generally, one finds that the 4th lumbar nerve is the *n. furcalis* in the great majority of cases; and further, that there is comparatively slight variability in the proximal and distal limits of the plexus. Under normal conditions, the peroneal nerve arose in ten cases from L.4.5.S.1, in nine cases from L.4.5.S.1.2; while the tibial nerve arose in ten cases from L.4.5.S.1.2, and in nine cases from L.4.5.S.1.2.3. It is apparently slightly more common to have a smaller than a larger number of nerves involved. This conclusion is supported by the condition found in abnormal cases, with L.5 as *n. furcalis*. In these cases the peroneal nerve is formed by L.5.S.1.2, or L.5.6.S.1; the tibial nerve by L.5.S.1.2.3, or L.5.6.S.1.2. This does not agree with Eisler's conclusion: he only notices incidentally and as an unusual occurrence the formation of the popliteal nerves from a smaller

number of spinal roots, and regards the larger number as undoubtedly the more usual condition.

II. *Origin of Branches from the Plexus.*—Eisler has given such an exhaustive account of the composition of the chief nerves arising from the lumbo-sacral plexus, that I propose here merely to compare briefly my results with his. Our results agree first of all in this, that the origin of the several nerves of distribution to the limb varies with the position of the *n. furcalis.* When tabulated, the conditions for the normal arrangement of the plexus being alone considered, and in my cases only averages being given, the results can be more easily compared.

TABLE II.

*Origin of Nerves of Lumbo-sacral Plexus.*

| NERVES. | Eisler. | Paterson. |
|---|---|---|
| Ilio-hypogastric | L.1 | (T.12).L.1 |
| Ilio-inguinal | L.1 | (T.12).L.1 |
| Genito-crural | L.2 | (T.12).L.1.2 |
| External cutaneous | L.2.3 | L.1.2.3 |
| Obturator | L.2.3.4 | L.2.3.4 |
| Accessory obturator | L.2.3 or 3.4 | (L.3) |
| Anterior crural | L.1.2.3.4 | (L.1).2.3.4 |
| Superior gluteal | L.4.5.S.1.(2) | L.4.5.S.1 |
| Inferior gluteal | L.5.S.1.2 | L.5.S.1.2 |
| Pyriformis | S.1.2 | S.1.2 |
| Obturator internus and superior gemellus | L.5.S.1.2.(3) | (L.4.5).S.1.2.3 |
| Quadratus femoris and inferior gemellus | L.4.5.S.1 | L.4.5.S.1 |
| Peroneal | L.4.5.S.1.2 | L.4.5.S.1.2 |
| Tibial | L.4.5.S.1.2.3 | L.4.5.S.1.2.3 |
| Small sciatic | S.1.2.(3) | S.1.2.3 |
| Pudic | S.1.2.3.4 | S.2.3.4 |

The points of difference between the two series are minor ones. In the plexuses which I have examined the 1st lumbar nerve has frequently been concerned in the constitution of the *genito-crural* and *external cutaneous nerves.* Except occasionally, I have not found the 1st lumbar entering into the composition of the *anterior crural;* and I have never found the 1st sacral assisting in the formation of the *pudic nerve.* Eisler records the existence of an *accessory obturator* nerve in 35 out of 120 cases (29 per cent.). This is a much higher proportion

than was met with in my cases. Indeed, among the 23 cases recorded in Table I., it was only present once and upon one side only. In three other cases not entered in the table (of plexuses in which, for various reasons, the dissection of the nerves to the limb was not completed), an accessory obturator nerve was found supplying the pectineus muscle (along with the anterior crural nerve) and the hip-joint, and communicating with the obturator nerve.[1] Eisler regards the accessory obturator nerve as closely associated with the obturator nerve proper, and as one of the ventral branches of the plexus. In another paper (13) I have adduced reasons for the opinion that it is to be associated rather with the anterior crural nerve, as one of the dorsal group of derivatives from the plexus.

[1] In the only case (a negro) among those in the Table (No. iv.) in which an accessory obturator nerve was found, it had an extraordinary distribution. Arising from the 3rd left lumbar nerve, between the roots for the anterior crural and obturator nerves, it takes the usual course over the pubis, and supplies the following six branches:—(1) a separate branch to the pectineus; (2) a small branch joining the nerve to the gracilis; (3) a branch joining the nerve to the adductor brevis; (4) a large branch which joins the cutaneous branch of the obturator nerve, and constitutes the greater part of a nerve which supplies the skin of the lower third of the thigh and inner side of the knee, and communicates with the internal cutaneous and internal saphenous nerves; (5) a branch passing deeply above the adductor brevis to the hip-joint; and (6) a branch which passes backwards above the obturator externus, and joining the deep part of the obturator nerve, communicates with the branches from it which supply the obturator externus, adductor magnus, and knee-joint respectively. On the right side of the same subject (No. vi.), the pectineus muscle received its nerve supply from two sources—one branch from the anterior crural nerve (from the 1st and 2nd lumbar nerves), and another small branch from the obturator nerve (from the 3rd and 4th).

*(To be continued.)*

# A VARIETY OF CURARA ACTING AS A MUSCLE-POISON. By JOSEPH TILLIE, M.D., F.R.S.E., *Senior Assistant to the Professor of Materia Medica in the University of Edinburgh; Medical Tutor, Royal Infirmary, Edinburgh.*

AFTER the publication of my paper[1] "On an Arrow-Poison from New Granada, and on its Botanical Source," Dr James Whiteford of Greenock very kindly presented to me a bamboo quiver containing 13 poisoned blow-pipe darts, which he had also obtained personally in 1862 from the chief of a branch of the Rio Verde tribe of Indians at a village named Musinga, situated about 50 to 60 miles to the west of the city of Antioquia (New Granada, South America), between the watersheds of the rivers Atrato and Cauca.

The curara on the darts was stated by the Indians to be solely of vegetable origin, and to have been obtained from climbing plants (Spanish, *bejucos*). The Indians also informed Dr Whiteford that they never used curara of animal origin, as they could obtain in their own neighbourhood climbing plants which yielded curara, some plants yielding stronger curara than others.

Dr Whiteford informs me that, in the district of Antioquia at least, the word *curara* and its variations, is simply the Indian term for the generic *poison* (Spanish, *veneno*), and that the word is applied to any poisonous substances, whether of vegetable or of animal origin. He was, for example, informed, without however being able to verify the statement, that the Indians in the upper valley of the Atrato obtained a poison from a small *frog*, and that this was "*muy buen curara*" (very good curara), an expression which illustrates the real meaning attached to the word. It would seem therefore that the poison is not called "curara from the plant *curari* from which it is obtained," as Taylor[2] mentions, but rather that various plants are called curari, woorali, &c., because they yield curara (*i.e.*, poison).

The only reference I have found concerning the curara of New

[1] *Jour. Anat. and Phys.*, vol. xxvii. p. 402, 1893.
[2] *Pharm. Jour.*, Dec. 1877, p. 424 (cit. *Taylor on Poisons*).

Granada occurs in Hammond and Mitchell's paper[1] on "Two New Varieties of Woorara, &c.," brought from the Rio Darien region in 1859, and is as follows:—"Our friend Mr Trautbine, late chief engineer of the Panama Railway, informs us that the arrow-poison employed by the Indians of the Rio Atrato, on the eastern[2] side of New Granada, is not at all powerful. He states that he has frequently wounded birds, pigs, and other animals with it without producing any marked result. The Indians, however, told him that they used a more virulent poison when they went to war, but, if this be true, he was unable to obtain any of it." Dr Whiteford also experienced no special difficulty in obtaining in the Antioquia district specimens of ordinary curara, but he informs me that he obtained the darts, which are here described, with considerable difficulty. This circumstance alone might lead to the suspicion that the darts are smeared with some special curara, or possibly with, as Mr Trautbine was informed existed, a "more virulent poison," used in warfare.

The 13 darts are similar in appearance. They are made of a light and somewhat flexible wood; the colour, both externally and on section, is a deep brownish-black. The average weight of a dart is 1·7 grammes (26·2 grains); and the average length is 23 centimetres (9 inches). The one end is sharpened to a fine point; the other is blunt, and has a diameter of 1·5 millimetres. The shaft is roughly rounded, and attains a maximum diameter of 3 millimetres at a distance of 8 centimetres from the pointed end, and gradually tapers to the blunt end. The tips of the darts have, for a distance of about 3 centimetres ($1\frac{1}{4}$ inch), a thin coating of a greyish-coloured firmly-adherent substance.

These New Granada blow-pipe darts resemble specimens of blow-pipe darts in the Materia Medica Museum of the University of Edinburgh, obtained in 1839 from the Macusi Indians, who inhabit districts about the Upper Essequibo, British Guiana. The Macusi darts are made of a light straw-coloured wood, and are much more neatly finished than the New Granada specimens. They are of three sizes, 23, 30, and 34·5 centimetres long respectively. They have a maximum diameter of 3 millimetres; the

[1] *American Jour. Med. Sciences*, vol. xxxviii. p. 25, 1859.

[2] The Rio Atrato is on the western, not the eastern side of New Granada.

longest size of dart weighs 2 grammes; and the tips of the darts are thinly covered, for a distance of 4 centimetres ($1\frac{1}{2}$ inch), with a black coloured substance which possesses the usual pharmacological actions assigned to curara.

On completely immersing the tips of 6 of the New Granada darts in 10 c.c. of distilled water, an almost perfectly clear solution of a deep yellowish-red colour was obtained after a few minutes. The darts were left in the water for 24 hours, and on their removal a dull yellow-coloured undissolved layer remained on the tips.

A few particles scraped from the tip of one of the remaining darts and placed on the tongue imparted a slightly bitter taste. The solution yielded by the 6 darts had a faintly acid reaction, and was tasteless. This solution, after filtration, was divided into two equal parts, one of which was evaporated to dryness at a temperature not exceeding 138° F., and yielded 0·024 gramme of a dark yellowish-red coloured substance having the form of an amorphous film, and possessing a slightly bitter taste. The other part of the solution was employed in carrying out the pharmacological examination, and was not subjected to heating or to any chemical process.

The 6 darts yielded to 10 c.c. of distilled water 0·048 gramme (0·024 grm. $\times$ 2) of substance. The moist undissolved residue was easily entirely removed from the tips of the darts in the form of flocculent particles and pieces, and weighed when completely dried 0·039 gramme. The total amount of substance on the 6 darts was therefore 0·087 gramme, of which 55·1 per cent. was readily soluble in water.

The undissolved substance showed, on microscopical examination, numerous amorphous yellowish-red particles, a few broken crystals and a few entire crystals (apparently oxalate of calcium), some globules (oil), and fragments of vegetable tissues.

A few colour reactions were tried with the small amount of dried soluble substance available. A drop of distilled water added to a few minute particles almost immediately produced a light yellowish-red coloured solution. A drop of solution of potash (*Ph. Brit.*) added to a few particles in the cold almost immediately produced a reddish-yellow colour slightly yellower than that produced by water. A drop of strong sulphuric acid

added to a few particles in the cold produced within a few minutes a dark red colour, changing within 15 minutes to a muddy brown colour. Strong nitric and strong hydrochloric acid, similarly added, each produced almost immediately a dark yellowish-red solution, changing in a few minutes to a light yellowish-red colour, which only differed slightly in shade from the solution in distilled water. When a few particles were gradually heated from 110° to 120° F. along with a drop of strong sulphuric acid, the very dark red colour at first produced changed within 15 minutes to a muddy brownish-red colour, having a tinge of green at the edge, and within 40 minutes a very faint olive colour was developed. When 10 per cent. sulphuric acid was employed the green tinge was within 30 minutes more marked, but no other distinct colour change was detected.

As the quantity of curara which was soluble in water and pharmacologically active only amounted, for the 13 darts, to 0·104 gramme, no chemical processes could be adopted for the isolation of the active principle. But, as the toxicity was considerable, it was possible to carry out a sufficient number of experiments to determine the prominent signs of poisoning and the cause of death, and to render evident that this curara possesses an altogether different action from what is expected, and is found, with singular uniformity, in the crude mixture of substances bearing the name curara, woorara, &c., and used as an arrow-poison by Indian tribes scattered over vast and widely separated regions in the north of South America.

The minimum-lethal dose, by subcutaneous injection, of that part of the curara which was soluble in water, was determined for the frog (*R. temporaria*) to be, according to the following table, about 0·000013 gramme per gramme weight of frog, the experiments being made at a temperature of 70° to 77° F.

The general effects produced by the poison were of a nearly uniform character in the experiments (Nos. 6, 7, 9, 10, 11) where death resulted one or two hours after the subcutaneous injection of more than the minimum-lethal dose.

Before 30 minutes usually the frog showed signs of uneasiness, and when at rest the anterior extremities were extended, and the attitude was erect. The volume of the respiratory movements then became irregular; deep respirations became less and

MINIMUM-LETHAL DOSE OF WATERY EXTRACT FOR FROGS.

| No. of Experiment. | Weight of Frog in Grammes. | Dose in Grammes. | Dose per Gramme of Frog. | RESULT. |
|---|---|---|---|---|
| 1 | 14 | 0·000100 | 0·000007 | No effects. |
| 2 | 13 | 0·000140 | 0·000010 | Very slight effects. Recovery. |
| 3 | 19 | 0·000240 | 0·000012 | Very slight effects. Recovery. |
| 4 | 13·2 | 0·000158 | 0·000012 | Death before 23 hours. Time not known. |
| 5 | 14·7 | 0·000192 | 0·000013 | Death in 25 hours. Probably a small part of the dose was lost or entered the stomach. |
| 6 | 17 | 0·000238 | 0·000014 | Death in 1 hour and 20 minutes. |
| 7 | 12·5 | 0·000187 | 0·000015 | Death in 2 hours and 37 minutes. |
| 8 | 20 | 0·000330 | 0·000016 | Death before 12 hours. Time not known. |
| 9 | 22 | 0·000480 | 0·000021 | Death in 1 hour and 10 minutes. |
| 10 | 20 | 0·002400 | 0·000120 | Death in 55 minutes. |
| 11 | 22 | 0·004800 | 0·000218 | Death in 55 minutes. |

less frequent; and within about 40 minutes irregular pauses in respiration occurred, and the rate soon fell to 5 or 6 per 60 seconds, with prolonged periods of total arrest. The mouth gaped during the period of interrupted respiration in experiment No. 11 only, where a large dose was administered. Meantime the frog leaped about vigorously, but soon the head sank to the ground, the leaps became uncertain, the extremities remained in any position, and, finally, the extension of the posterior extremities was too feeble to produce any change in the animal's position. At this time no cardiac movement was to be observed on inspection of the thoracic region. The feeble voluntary movements soon ceased, but, on stimulation, reflex movements were still readily obtained, and also movements of the respiratory muscles at the lower jaw. Very slight fibrillary twitches of those superficial muscles brought into contact with the injection were observed in Experiment No. 10 only.

On immediate *post-mortem* examination, the veins were found to be distended, and the muscles very pale in colour. On opening the thorax the heart was found to be motionless. The auricles were distended with blood, and dark in colour. The ventricle was usually empty, and in a condition of marked systole, the colour being pale or a mottled red. At this stage, neither mechanical stimulation of the heart, nor electrical stimu-

lation by means of a very strong interrupted current caused any pulsation; but, when the ventricle was somewhat relaxed and red in colour, the stimulation caused it, within a minute or two to gradually pass into permanent contraction and to become pale.

A moderately strong current from a single bichromate cell and Du Bois Reymond's induction apparatus, applied to the upper end of the spine, immediately after all voluntary and reflex movement had ceased, caused general tetanus. Also, when one sciatic nerve was divided, stimulation of the upper end caused no reflex movement, but stimulation of the lower end readily caused tetanus of that lower extremity.

The disappearance of voluntary and reflex movements is due to paralysis of the central nervous system, because, when, in a brainless frog, one leg is protected by ligature of the vessels before the poisoning, the movements of both legs and the reflex effects produced by stimulation of the skin of either leg are equal, and the voluntary and reflex movements disappear in both the poisoned and the unpoisoned leg at the same time. The period at which the paralysis of the central nervous system occurs indicates that it is secondary to the arrest of the circulation.

Muscular rigidity set in very early, especially in the thoracic muscles. On the day following the experiment the frog was always in a state of strong general rigor, and the muscles were acid in reaction, and (with the exception of a protected part and sometimes of the unprotected muscles of the foot) were inexcitable to mechanical or electrical stimulation.

Stimulation of a motor nerve, after death, continued to cause muscular contractions until the muscles themselves, by only responding to stronger and stronger direct electrical stimulation, showed distinct signs of poisoning. In one experiment (No. 13), where a small dose of curara was employed, the sciatic nerves were found to be excitable 12 hours after the heart was paralysed, but, 10 hours later, the muscles were paralysed.

When, in pithed frogs, the poison was applied directly to the heart, after removal of the pericardium, the results varied according to the dose employed. When the dose was about the exact minimum-lethal, the heart continued to pulsate for several hours, the rate then became very slow, and the rhythm, owing to

prolonged periods of stoppage in extreme diastole, became very irregular. During the period of arrest in diastole, the heart readily contracted on stimulation. For example—0·00015 gramme of the poison, in solution in about half a minim of distilled water, was applied at 3.48 p.m. to the heart of a frog, the rate being 56 per minute, and the systole and diastole normal. In 17 minutes, the rate was 44 per minute, and the heart was acting more vigorously, the diastolic expansion being greater and the ventricle paler during systole. In 42 minutes, the rate had fallen to 24 per minute, the slowing being due mainly to the lengthening of the pause in diastole. The diastolic expansion was a little less, and the systole more complete than before. In 58 minutes, the rate was 16 per minute, and, then, for 2 hours the rate varied quite irregularly, but rarely exceeded 5 per minute. Pauses in complete diastole continuing for from 40 to 100 seconds frequently occurred, both auricles and ventricle being greatly distended. When the heart resumed pulsating, sometimes the auricular contractions took place first, sometimes the ventricle acted alone during a few minutes, and sometimes the whole heart seemed to contract at once. The infrequent ventricular contractions were extremely vigorous. After 4 hours the rate rarely exceeded 1 per minute, but, at any time, slight mechanical stimulation during a pause caused contraction, although after stimulation had been several times repeated the diastolic expansion seemed smaller. On the following day the heart was found motionless, with the ventricle moderately contracted, but not affected by mechanical or electrical stimulation.

When the dose was considerably in excess of the minimum-lethal, the ventricle was arrested within 10 or 20 minutes, but retained its excitability for about 20 minutes longer, when it passed into a condition of extreme and permanent systole. The auricles were affected after the ventricle. For example:—In a frog weighing 19 grammes, 0·00096 gramme of curara in solution in 3·5 minims of distilled water, was applied in small drops, during 5 minutes, to the exposed heart, which was acting normally at the rate of 40 per minute. In 9 minutes, the rate was 32 per minute; the ventricle was paler during systole than before, and the diastole was less complete, one side of the

ventricle looking a little paler during the diastole than the other; the auricles looked larger, not apparently being fully emptied during systole. In 11 minutes, the ventricle suddenly stopped in medium diastole—the cavity being fairly well filled, and the colour of the ventricle quite red. The auricles meantime continued to pulsate at the rate of 36 per minute. After a pause of 45 seconds, the ventricle resumed contracting for 1 minute at the rate of 12 per minute, then stopped in medium diastolic expansion for 7 minutes; then it contracted quite regularly, without any stimulation having been applied, for 32 seconds at the rate of 32 per minute, when it permanently ceased to contract spontaneously. The auricles all this time were acting regularly at the rate of 32 per minute, they then stopped for 70 seconds, 2 minutes after the permanent arrest of the ventricle, and during the next 3 minutes, 4 contractions occurred, and then the auricles ceased to pulsate spontaneously. The auricles still responded to mechanical stimulation for 2, and the ventricle for 8 minutes longer. At this time slight fibrillary twitchings of the thoracic muscles were occurring, and the general reflexes produced by stimulating the skin were excellent.

These few experiments suffice at least to indicate that the most prominent features of the pharmacological action of small and moderate doses of this curara in the frog are:—

1. Rapid and absolute paralysis of the muscle of the heart, the respiration continuing.

2. Absolute paralysis and rigidity of the skeletal muscles at a much earlier period than happens in the case of an animal whose circulation has been artificially arrested.

3. Exemption of the motor nerves from paralysis until after death, and until the muscles show signs of poisoning.

A sufficient quantity of the curara remained after the experiments on frogs to allow of the administration to a rabbit of a dose which was lethal, and which, since it was approximately the minimum-lethal dose per gramme weight of frog (0·000013 gramme) multiplied by the weight of the rabbit in grammes (1814 grammes), was probably near the minimum-lethal.

At 4.40 p.m., 0·024 gramme of curara dissolved in 1·5 c.c. of water was injected subcutaneously, the temperature of the room

being 80° F., and the animal's respirations 60 per 15 seconds. During the next 20 minutes (up to 5 p.m.), the respirations continued at the same rate, the rate of the heart being 70 per 15 seconds; and nothing unusual was noticed in the animal's attitude or movements. In 30 minutes (5.10 p.m.), the respirations slowed for a second or two occasionally; the animal either rested in an extended position on the thorax or in a sitting position; and the lips were licked occasionally (salivation ?) and rubbed with the paws. In 34 minutes, the respirations were 55; in 39 minutes, 46; and in 50 minutes, 40 per 15 seconds. At this point (5.35 p.m.), signs of asphyxia set in, the respirations quickly becoming extremely shallow and slow, the rate varying from 6 to 10 per 15 seconds, with intervals when apparently little or no air entered the lungs, but inspiratory attempts continued, as shown by gaping and snapping movements of the mouth; and slight movements of air were indicated by whistling laryngeal sounds, chiefly with expiration. Coincident with the onset of marked respiratory difficulty, the exact time relation not being determined, the rate of the heart was found, by palpation of the thorax, to be only from 20 to 25 per 15 seconds, and the rhythm to be irregular and the impact feeble. During 22 minutes (until 5.57 p.m.), the slow, laboured, extremely shallow respiration continued. The heart, however, distinctly recovered during the first half of this period, the rate increasing to 40 and then to 50 per 15 seconds, and the rhythm becoming regular, and the impact fairly strong; but, during the second half, the action of the heart became irregular, rapid, and so feeble that only a fluttering movement was perceptible. During the whole 22 minutes the animal was able at will to maintain a sitting position, with the head and ears erect, or to move about. In 77 minutes, the respirations consisted only of snapping movements of the mouth and mere quiverings of the muscles of the abdomen; the heart movements were scarcely perceptible to palpation; the head began to sink to the ground; and urination occurred. In 82 minutes, the animal lay prostrate on its side, but could still rise voluntarily; the heart movements seemed to palpation to be mere quiverings; the respirations entirely failed; and no fibrillary twitchings were observed. A minute later violent tetanus set in, and the pupils dilated widely.

At 6.4 p.m., about 84 minutes after the administration of the curara, three gasping inspiratory movements occurred; no cardiac impact could be felt; contraction of the pupils soon began; and the motion of the abdominal walls showed the occurrence of intestinal peristalsis.

Six minutes after death the heart was exposed. The auricles contained some blood; the right ventricle was distended with blood, and the left was empty. Slight mechanical stimulation of the auricles caused no movement, but, when applied to either ventricle, the stimulation caused, on three or four occasions, a few quivering movements, but no complete pulsations. About 16 minutes after death, one sciatic nerve was exposed, and stimulated by means of the strongest current from a single bichromate cell and Du Bois Reymond's induction apparatus, without any result, but on testing the muscles themselves, it was found that, with the exception of some of the facial muscles, they did not contract on direct stimulation. About 41 minutes after death rigidity had distinctly commenced, but some of the facial muscles still contracted on electrical stimulation; the blood in the right ventricle was found to have coagulated, and the muscle of the left ventricle was very hard. About 54 minutes after death (7 p.m.), the reaction of the heart muscle and of the muscles of the thigh was taken, and found to be acid.

The absence of motor weakness until near death, the marked action upon the heart, and the early total paralysis of muscles and onset of rigidity, at once distinguish the prominent actions of this curara from those of ordinary curara, which, as is well known, causes death by producing an asphyxia due solely to paralysis of the motor nerves, and does not affect the heart or muscles. In the case of this curara, one experiment on a warm-blooded animal is quite insufficient to show the exact cause of the prolonged respiratory difficulty, but phenomena quite similar in kind occur after the administration of other muscle-poisons.

This specimen of the South American curara resembles in action, therefore, the Strophanthus[1] type of the African arrow-poisons. It possesses a similar action to the "Woorara, variety Corroval," and the "Woorara, variety Vao," investigated very

[1] Fraser, *Trans. Roy. Soc. Edin.*, vol. xxxvi. part ii., 1891.

fully by Hammond and Mitchell[1] in 1859, but the botanical origin of which is unfortunately unknown.

Although it is not known from what plant or plants this curara from Antioquia which I have described is derived, it is highly probable that, like the curara of Guiana, Venezuela, and Brazil, it is got from one or more species of *Strychnos*, for, of course, it is not at all necessary that the members of the same botanical genus should yield the same active principle. My reason for coming to this conclusion is that, in 1889, I obtained from the Herbarium of the Royal Gardens, Kew, a piece of stem of an unknown but unmistakable *Strychnos* plant which had been collected in the same district (Antioquia) from which these darts were obtained, and had been forwarded to Kew as the source of a curara. I found,[2] however, that a watery extract prepared from the bark had, in frogs, no primary action upon motor nerves, but caused cardiac paralysis. In these actions the extract agreed with that obtained from the *Strychnos Gardnerii* of Brazil,[3] but differed altogether from the extract prepared from the bark of the *Strychnos toxifera*[4] of British Guiana.

In view of the fact that it is now definitely known *by experiment* that curara may consist of curarine-acting or digitalin-acting principles, or of mixtures[5] of these in unknown strength and proportion, it is impossible, without a careful preliminary experimental examination of each specimen, to employ crude curara, in place of the alkaloid curarine,[5] in accurate physiological experiments on the circulation or upon muscle, much less (as is unfortunately recommended in several works of Materia Medica, and by the British Pharmaceutical Conference[6]) as a therapeutic agent to be administered by hypodermic injection.

[1] *Loc. cit.*, pp. 34 and 58.
[2] *Jour. Anat and Phys.*, vol. xxv. p. 57, 1890–91.
[3] MM. Couty et De Lacerda, *Compt. rend.*, vol. lxxxix. p. 1035, 1879.
[4] *Jour. Anat. and Phys.*, vol. xxiv. p. 403, 1889–90.
[5] Boehm, *Chem. Stud. über das Curare*, p. 180, 1886, Leipzig.
[6] *Unofficial Formulary*, 1888, p. 14.

# OBSERVATIONS ON THE APPENDIX OF THE TESTICLE, AND ON THE CYSTS OF THE EPIDIDYMIS, THE VASA EFFERENTIA, AND THE RETE TESTIS.

By JOSEPH GRIFFITHS, M.A., M.D., F.R.C.S., *Assistant to the Professor of Surgery in the University of Cambridge, Pathologist at Addenbrooke's Hospital.* (PLATE II.)

IN the last three to four years I have examined many testes, with the object of determining the structural nature of the little bodies found in and near the upper end of the epididymis in persons above middle age, and known as "hydatids" (or cysts); and of ascertaining the mode of origin of the spermatozoa-containing cysts of this region.

Among the "hydatids" first noted by Morgagni (1) is a small solid body attached to the tunica albuginea of the testis at the upper and fore part of the organ, which is not cystic, and therefore essentially different from the others. This body I have called the "appendix" of the testicle, after Gosselin (2) (ungestielte hydatid of Luschka), in order that it may be differentiated from the little cysts ("hydatids") which arise in and remain attached to the upper end of the epididymis. With regard to the spermatozoa-containing cysts, it will be pointed out further on that they may arise by dilatation of the tubules of the epididymis, of the vasa efferentia, or of the rête testis, and that the cysts which take origin in the vasa efferentia or rête testis are those which commonly assume a large size, and come under the notice of the surgeon.

## *The Appendix of the Testicle (so-called "Hydatid of Morgagni").*

The appendix[1] of the testicle is a small body situated on the upper and front part of the body of the testis, just in front of the globus major or head of the epididymis.

[1] I have found this appendix in the horse, occupying the same situation and presenting the same structure as in Man. I have found it in no other animal.

It is in the young (in whom it is, so far as I have observed, always present on both sides) a flat, tongue-like process, with a wrinkled or corrugated surface, hanging into the cavity of the tunica vaginalis, and having a flat, band-like attachment at its base to the tunica albuginea of the testis, through which a few blood-vessels may be seen running into its substance. It measures from $\frac{1}{6}$ to $\frac{1}{3}$ of an inch in length, and sometimes even more. In the adult it may be found of the same size as it is in an infant, or it may be so shrunken as to be hardly recognisable as the same body were it not for the situation in which it is found. It may be globular and firm, or much reduced, even to a mere stump. Not unfrequently it is altogether absent. Accordingly, it is best seen in early life.

A microscopic examination of it in a boy shows it to consist of a process of fibrous connective tissue, which arises at right angles from the surface of the tunica albuginea, and which is directly continuous with the superficial layer of that tissue (fig. 1). Through this connective tissue many blood-vessels traverse, which are quite out of proportion, both in number and size, to the needs of the structure itself. The surface of the appendix is wrinkled or thrown into irregular folds, and it is covered by a single layer of cells, which are best described as sub-columnar. These rest upon a basement membrane formed by condensation of the outermost layers of the connective tissue constituting the substance of the body, and are directly continuous with the flat endothelial cells lining the tunica vaginalis on the one hand, and covering the tunica albuginea on the other,—the transitional forms from the columnar to the flat variety being seen where the appendix joins the tunica albuginea. In no instance have I found in the interior of this body any glandular tubules, or any remains of true epithelial cells. The grooves produced by the wrinkling of the surface, seen in section, resemble tubules passing inwards; and this may perhaps have suggested to former observers the apparent glandular nature of this little body.

In the adult, as I have said, the appendix is usually reduced in size. It may, however, be found somewhat large and globular, owing to an increase of its fibrous connective tissue, and to the formation of cystic dilatations, which in all the

examples I have met with were mere dilatations of lymph spaces, and not the result of distention of pre-existing gland-tubules. However altered the condition of the appendix, the epithelium on the surface retains its sub-columnar shape, and shows no tendency to become flattened.

This little body, which Morgagni (1) first drew attention to, and which was by him considered, by its rupture, to be one of the causes of vaginal hydrocele, has usually been regarded as one of a group of small, pedunculated cysts that are found attached to the upper end, or globus major of the epididymis. But a careful inspection will at once show that it is quite distinct from the small pedunculated cysts described in the next section of this paper, and bears no resemblance to them except in proximity of position. It differs from them in structure, in situation, and in the time of life at which it is best seen.

Morgagni (1) rightly described it as a flat body with a corrugated surface, and added, as his opinion, that primarily it is of a cystic nature, but that the cyst usually bursts, and leaves the body corrugated as we find it. Hence he calls it a collapsed hydatid (or cyst). Gosselin (2) dissented from this view, and called it the *appendix testiculaire.*

Kobelt (4) points out that this body (the appendix) arises at the free extremity of the Müllerian duct in early embryonic life, and into the base of which the remains of that duct may be traced in many instances in adult life.

Waldeyer (6) and many others agree with Kobelt, and, accordingly, this body has been regarded as the homologue of one of the fimbriæ at the free end of the Fallopian tube in the female; and it resembles them in so far that it consists of a basis of fibrous connective tissue, traversed by large blood-vessels, and covered by a single layer of sub-columnar epithelial-like cells.

Roth (5) has more recently given evidence pointing to the view that it marks the seat where the vasa aberrantia of the *upper*, or *fore* end of the Wolffian body terminate in an extremity usually blind, or, it may be, opening by means of tubular channels into the cavity of the tunica vaginalis. His investigation was carried out for the express purpose of showing how spermatozoa may escape into the cavity of the tunica vaginalis and contaminate the fluid in that cavity, the vasa aberrantia being supposed to establish a communication between the tubules of the epididymis and the serous sac surrounding the testis. Into this point I don't wish to enter here, but merely express my dissent from the view given by Roth.

I believe, as I have already said, that the tubular or glandular nature of this body is apparent only, the gland-like appearance being produced by the wrinklings, corrugations, or foldings of the surface which is covered by sub-columnar epithelial-like cells.

Luschka (3) in his paper gives a very good description of the villous (zotten-artige) bodies found on the tunica vaginalis covering the body of the testicle, and to that group possibly it may belong. It

may, however, be the representative of one of the villous processes at the free extremity of the Müllerian duct (Fallopian tube), as suggested by Kobelt and by Waldeyer (6).

Its structure does not give a clue to its nature, but it is so constant a feature in the testicle of the young that it deserves some distinctive name, such as the "appendix" of the testicle; and it must not be confounded with the cystic or hydatid bodies that are found in this neighbourhood.

## CYSTS OF THE EPIDIDYMIS.

The epididymis may, for convenience in the study of its cystic diseases, be divided into two parts,—(1) an upper third, and (2) a lower two-thirds, or convoluted duct part. The upper part, globus major, or head of the epididymis, as it is sometimes called, is composed of a number (twelve to fifteen or more) of small lobules, which are bound together by the tunica vaginalis, yet separated from one another by means of fine partitions of loose, fibrous connective tissue, through which the blood-vessels and nerves run: these partitions are continuous with the serous covering. There are the same number of lobules in this part as there are of efferent ducts leading from the rête testis; and from each lobule a small duct passes into the commencement of the vas deferens. Thus each lobule corresponds with an efferent duct of the testis, and its tubules are in communication, on the one hand, with the rête testis, and on the other with the vas deferens; and each lobule is independent of its fellow, and may be diseased or destroyed without in the least affecting the function of its neighbours. For example, the tubules of one lobule may be found in an advanced stage of chronic inflammation, presumably functionless, while the neighbouring lobules may be perfectly healthy: this, at least, I have found in several instances to be the case.

The lower two-thirds of the epididymis, which is composed of the convolutions of the commencing vas deferens, closely bound together by fibrous connective tissue, is not liable to undergo cystic changes, and consequently no further mention of it will be made in this paper.

The cysts met with in the upper end of the epididymis group themselves under the following headings:—

1. Small, pedunculated, and sessile spermatozoaless cysts, so-called "hydatids," which arise between the tubules.

2. Single spermatozoa-containing cysts which arise from localised dilatations of the tubules.

3. Multiple spermatozoa-containing cysts, involving, as a rule, the tubules in one or more lobules (coni vasculosi).

### 1. *Small, Pedunculated, and Sessile Spermatozoaless Cysts, so-called "Hydatids," found between the Tubules of the Epididymis.*

Multiple, small, clear, translucent cysts, both pedunculated and sessile, are frequently found attached to the upper end of the epididymis, in the testicles of persons beyond the age of forty years. Occasionally they are found in earlier life; but as a general rule they appear at and increase in number after middle age, so that it is uncommon to find them absent in persons above forty. Usually they are very small, rarely exceeding the size of a currant, that is, about ¼ inch in diameter, though they may be found nearly twice that size. The pedunculated cysts are attached to the epididymis by a short or long narrow stalk, which may be an inch or more in length; along this stalk small blood-vessels travel to the free end which contains a small and it may be tense translucent cyst. The *sessile* cysts may be seen lying among the tubules, just under the serous membrane, or they may have partially emerged and be on their way to become stalked, or pedunculated. Thus the pedunculated variety arises from the *sessile*, the latter departing from their seat of origin in the epididymis, first projecting the serous covering, and then protruding more and more till they are attached to the epididymis only by a thin process of the tunica vaginalis.

Under the microscope these cysts, whether pedunculated or sessile, are seen to consist of a distinct cyst-wall, with an epithelial lining composed of a single layer of columnar cells which, so far as I have observed, are not ciliated (fig. 2). This layer of cells rests directly upon the cyst-wall, which is composed of a thin layer of spindle cells resembling unstriped muscle fibres, together with a small amount of fibrous connective tissue.

In the pedunculated variety there is, of course, in addition, the tunica vaginalis. The fluid which they contain is clear and watery, slightly albuminous; and in it may be found numerous granules, a few small cells with large nuclei and granular protoplasm, but no traces of spermatozoa.

No connection can be traced between these cysts and the tubules of the epididymis, beyond the fact that they take origin from their midst.

Luschka (3) also failed to find any spermatozoa in these cysts, or to trace any connection between their cavities and the tubules of the epididymis. Gosselin (2) agreed in these respects with Luschka, and so have practically all subsequent writers.

In regard to the possible mode of origin of these small spermatozoaless cysts of the epididymis, reference may be made to the researches of Kobelt (4), already noted. In these the Wolffian body is traced through all the changes that occur in it during embryonic life, and the parts of it that continue to develop and become permanent are differentiated from those that more or less disappear, and leave only slight remnants of their former tubular structure. The tubules of that body (Wolffian) are divided into three sets—an anterior, a middle, and a posterior; the former and the latter disappear, while the middle set continue to develop and become transformed into the coni vasculosi, that constitute the upper end of the epididymis. He found, in his dissections of the testicle of an adult, small stalked cysts attached to the tubules of the epididymis. These he regarded as the outcome of subsequent growth in the unobliterated anterior tubules of the Wolffian body; and the vas aberrans Halleri as the representative of one of the posterior tubules, which failed to develop into a conus vasculosus.

There is, however, no evidence to show that the cysts do actually thus arise, but, on the contrary, even Kobelt's dissections show that these small cysts, which may be found between the tubules of the epididymis, have an attachment to those tubules, a condition hardly to be expected if they originate as independent cysts from undeveloped remains of the tubules of the Wolffian body; from Kobelt's view Klebs dissents.

I infer that these small spermatozoaless cysts originate, being outgrowths or buds from the sides of the tubules, and, early

losing their connection with the tubules, do not contain spermatic fluid, but simply a serous fluid, probably secreted by the columnar cells lining their walls. Whereas, the spermatozoa-containing cysts, as will be pointed out in the next section, result from dilatation of a tubule in part or in its entire circumference, and these retaining their connection with the tubules of the epididymis, are capable of being distended with the spermatic fluid formed in the body of the testicle.

### 2. *Single small Spermatozoa-containing Cysts which arise from localised Dilatations of the Tubules of the Epididymis.*

Single cysts are not unfrequently met with in the upper third of the epididymis in men above 40 years of age. They vary in size from one quarter to an inch in diameter, and they are always, so far as I have observed, in part embedded in the substance of the epididymis. They are usually composed of very thin walls, and they contain thin watery fluid, in which numerous spermatozoa may be found, but, as a rule, only a very small percentage of albumen. Within, and lining the cyst-wall, is a single layer of non-ciliated columnar epithelial cells, which are shorter and smaller than those lining a normal tubule of the epididymis; these epithelial cells, owing perhaps to the pressure they are subjected to by the fluid contents of the cysts, lose their cilia and tend to become cubical. The wall itself is composed of two distinct layers,—an *inner*, in which there is much elastic tissue in the form of fibres embedded in a fibrous matrix, and here and there some remains of unstriped muscular fibres; and an *outer* thin coat, composed entirely of fibrous connective tissue, which is derived from the connective tissue stroma of this part of the epididymis.

Sometimes such a cyst may be found with a thick wall and with the interior filled with a yellowish granular substance which is found under the microscope to be composed of epithelial cells, debris, and heads of spermatozoa. Evidently these are cysts like the above, which have undergone a further change.

These are sometimes known as the sessile "hydatids of Morgagni." Luschka (3) demonstrated that these *non-pedun-*

*culated* cysts, as he called them, were, when they contained spermatozoa, always in communication with the tubules of the epididymis, and from them he could inject with mercury the neighbouring tubules. Since his writing, the same relation to the tubules of the epididymis has been demonstrated on several occasions; but there still seems to be some doubt as to whether these cysts are primarily dilatations of a portion of the tubule in a conus vasculosus, and so merely a dilated portion of the seminal excretory apparatus, or whether they are cysts which arise independently of the glandular tubules, and into which one of the neighbouring tubules ruptures and discharges its portion of the seminal secretion of the testes. The structure of the walls of the cysts, their epithelial lining, their situation, their contents, and the fact of their communication with the tubules of the epididymis, all appear to be in favour of the cyst being simply dilatations of the tubules in a given conus vasculosus. In short, that they are retention cysts.[1]

### 3. *Multiple Spermatozoa-containing Cysts, involving the Tubules in one or more Lobules of the Epididymis.*

A not unfrequent condition found in the upper end of the epididymis in men above forty is cystic dilatation of the tubules in one or more of its lobules. Such cysts are usually very small and very numerous, and filled with spermatic fluid containing numerous spermatozoa. The condition is well shown in fig. 4, which was taken from a section through the upper end of the epididymis thus affected. In this the tubules, or circumscribed portions of them, are dilated to several times their natural size and sometimes to the size of a pea; and as the dilatations increase they become more and more pressed together, and the intertubular connective tissue becomes less in amount, denser, and more fibrous. The wall of each cyst consists of a thin muscular

[1] Hochenegg, in his paper, describes these cysts under the term "Intravaginal spermatoceles," in contradistinction to the "Extra-vaginal," which are the more common and which arise from dilatation of the *vasa efferentia*. In reality both kinds are extra-vaginal, for all the cysts of the epididymis are covered by the visceral layer of the tunica vaginalis that covers the upper end of the epididymis.

coat, which is the flattened-out thick muscular coat of the normal tubule; here and there the muscular fibres are replaced by fibrous connective tissue. Each cyst is lined by a single layer of columnar non-ciliated (the cilia having disappeared) epithelial cells, which are, in most instances, not so large as those found in the natural tubule. The nuclei of these cells are small and their protoplasm is often clear, although in some instances it contains fat granules from fatty degeneration. Between the attached ends of these cells, other smaller cells are found. The lumen or cavity is occupied by numberless spermatozoa and a few large round cells.

Some of the dilated tubules undergo an unequal dilatation, the sides bulging outwards in the form of saccules, as shown in fig. 6, which appearance has been described by Arthaud (9) as "varicosity" of the tubule.

This cystic condition of one or more lobules is sometimes associated with an opposite condition in other lobules, namely, diminution of the size of the individual tubules, and an increase in thickness and density of the inter-tubular connective tissue; a condition, that is, which may be referred to a chronic inflammatory process. Whether the cystic state just described may be due to a similar process I must at present leave.

Thus three different cystic conditions may be met with in the upper end of the epididymis, and all of them possess certain features in common. They all occur about and after forty years of age; their walls are composed of fibrous connective tissue, in which there are found unstriped muscle fibres, and they are lined by a single layer of columnar or cubical epithelial cells which bear no cilia. So far they resemble one another. They differ, however, in that the small pedunculated and sessile cysts, which are almost without exception multiple, contain serous fluid, in which no spermatozoa can be found, while the single cyst and the cystic dilatations of the tubules of the epididymis, in one or more of its lobules, contain spermatic fluid, in which spermatozoa are abundant. Thus the chief pathological difference between them lies in the fact that one set of cysts contains serous fluid, devoid of the sperm element, while the other two contain the typical sperm-fluid. The last two are essentially the same, but

in the one the cyst is single, and may attain to the diameter of half an inch or an inch, whereas in the other the cysts are small and numerous—the cystic condition affecting the tubules in their entirety in one or more lobules.

## CYSTS ARISING FROM THE VASA EFFERENTIA AND THE RETE TESTIS.[1]

The cysts in the upper end of the epididymis above described rarely attain any large size, and they do not, in consequence, come under the care of the surgeon, but the cysts that I next describe often assume considerable dimensions, and not unfrequently become the subject of treatment.

These cysts are situated in the tissue that intervenes between the back of the body of the testis and the epididymis, and especially in that part subjacent to the upper end or globus major of the epididymis.

We have here the plexus of channels known as the rête testis and the vasa efferentia. The former (rête testis) occupies the corpus Highmorianum which is placed at the hinder and upper part of the body of the testis. The vasa efferentia, fifteen to twenty or more in number, arise from the rête and pass upwards to reach the under surface of the upper end or globus major of the epididymis, near which they become very convoluted. The plexuses of the rête are supported by fibrous connective tissue, so that the tubules would not readily yield to internal pressure; and, as a matter of fact, they but rarely undergo distention. The vasa efferentia, however, which are composed of somewhat delicate walls, pass to their termination in the coni vasculosi of the epididymis through loose areolar tissue which affords them no support. Consequently, owing to the thinness of their walls and the want of external support, they not unfrequently undergo dilatation, which may proceed until cysts of considerable size are formed.

As the cyst (it is usually single, or it may be accompanied

[1] Spermatic cysts that arise in these structures are included by Hochenegg (8), to whose writings reference has already been made, under the term "Extravaginal Spermatoceles," but that term has not been adopted by me for reasons before given (preceding foot-note).

with smaller additional cysts) enlarges, the epididymis is pushed outwards and to one side, so that the cyst projects upwards either into the interior of the spermatic cord, or into the cavity of the tunica vaginalis. As a general rule, the cyst is covered in its lower and fore part by the tunica vaginalis, and in its hinder and upper by the various tissues of the spermatic cord. Not unfrequently such a cyst occurs in each testicle, though it is more usual to find the affection on one side only,—on the right more frequently than on the left. Such cysts are chiefly found in men well above middle age, though they may be met with at the early age of twenty-five years. They usually contain a thin, watery, slightly opalescent fluid, holding in suspension countless spermatozoa which, when recent, often show active movements under the microscope. In the fluid there is only a small percentage of albumen.

In two of the following examples the cysts are single and large, and in the remainder the cysts are also large and associated with innumerable smaller cysts.

I. The first of these was taken from the left side of a man aged 63 years. The cyst, which was about the size of a pigeon's egg, was single, though at its lower part a few minute locules could be detected opening into it; these small locules were distended when air was blown into the larger one, so that they were thus brought into prominence and demonstrated. The cyst had taken origin between the epididymis and the back of the body of the testis, and in its growth had pushed aside the former, and grown towards the cavity of the tunica vaginalis. Its walls were very thin, translucent, smooth on their inner surfaces, lined with cubical non-ciliated epithelial cells, and in great part covered on the exterior by the stretched tunica vaginalis. It contained the ordinary spermatic fluid, in which were numberless spermatozoa. A section of this cyst, with the epididymis and body of testis, is shown in fig. 8, the epididymis is outside the cyst-wall and shown by the darker shading.

II. The second specimen was from a middle-aged man. The cyst, which was single, was the size of a duck's egg, with the narrow end upwards, and in great part embedded in the structures of the spermatic cord. It had taken origin in a vas efferens, near the rête testis, and had pushed the body of the epididymis to one side. A small round opening in the lower part of the cyst could be seen, through which fluid could be pressed from the rête. The fluid was like the typical spermatic fluid, namely, thin, watery, slightly opalescent, and containing many spermatozoa. There were no small locules connected with this cyst.

There were no other cysts in either of these cases, nor were there

any obvious changes from the natural state either in the epididymis or in the body of the testis.

III. The third specimen, from a man aged 54 years, showed one large cyst, as in the preceding cases, and in addition there was dilatation of several vasa efferentia into small cysts. There was also dilatation of the anastomosing channels of the rête. The large cyst, after being emptied, was distended with air, and the greater number, though not all, of the remaining cysts were distended through it. The cysts, large and small, occupied the usual position, namely, between the epididymis and the body of the testis, and had in their growth displaced the former outwards and to one side. In figs. 8, 9, which represent a section through the epididymis, cysts, and body of the testis, are seen the one large cyst, the size of a pigeon's egg, which had thin translucent walls; below this are several smaller cysts, of $\frac{1}{8}$ of an inch or less in diameter. Furthermore, the anastomosing channels of the rête testis are seen with the naked eye to be dilated. In the natural state they are not thus visible. The epididymis, as well as the body of the testis, shows no abnormal changes.

IV. *and* V. The fourth and fifth specimens showed the same condition as that described in the third. They were from a man 71 years of age. In the right testicle there was one large cyst of the size of a pigeon's egg, associated with numerous smaller cysts in the situation of the vasa efferentia. The larger cyst had in its growth displaced the epididymis outwards. All the cysts had very thin, almost translucent walls, with a smooth interior; and when the large cyst was emptied, all were emptied also; and likewise, when the larger cyst was distended with air, all the smaller ones were distended. This distention with air before hardening helped to demonstrate their existence.

In the left testicle the same cystic changes had taken place, but here the large cyst was at least three times larger than the one on the *right* side.

In both instances the fluid removed was watery, slightly opalescent; and in it there were numerous spermatozoa, but only a small amount of albumen.

*Microscopic Structure.*—Under the microscope the walls of these cysts, great and small, were seen to be composed of a thin layer of dense fibrous connective tissue, lined by a single layer of epithelial cells which in the larger cysts were of a low cubical variety or almost flat, and in the smaller sub-columnar, bearing however no cilia. It would appear that when tubules lined by columnar cells bearing cilia become dilated, the cilia first disappear, and then the columnar cells become reduced to a cubical or even flat shape, owing, doubtless, to pressure and dilatation of the cyst wall. Here and there few traces of unstriped muscle fibre could be seen in the walls of the cysts.

In a section through the upper end of the epididymis and subjacent cysts, in one of the cases (IV.) described, the manner in which the cysts arise was seen, for at the convoluted extremities of a vas efferens, where it is becoming a conus vasculosus, it presents numerous irregular dilatations; and it may be assumed that these dilatations are incipient cysts. This would also explain the communication that exists between the cysts.

Since the detection of spermatozoa in cysts of the testis by Liston (12) and Lloyd (13), various suggestions have been made to account for their occurrence. Liston was of opinion that the cysts were dilatations of some of the ducts leading from the testis, and that spermatozoa, being natural to the tubules, could also be found in the cysts; others supposed spermatozoa accidentally found their way into the cysts during the operation of tapping, the trocar puncturing one of the ducts of the testis. Paget put forward the view "that certain cysts seated near the organ which naturally secretes the material for semen, may possess a power of secreting a similar fluid." Curling (4) offered the following explanation:—"That their [spermatozoa] presence was probably owing to rupture of one of the tubes of the epididymis, and the escape of semen into the sac of the hydrocele." He supposed that all cysts which developed in this region were originally the same as the small, usually multiple, *spermatozoa-less cysts* of the upper end of the epididymis (see p. 111); and that as these cysts grew, they pressed upon and stretched the tubules of the epididymis, which would, under such circumstances, readily give way and rupture into the cyst. He and Queckett (5) injected the vas deferens with mercury in several instances, and found a communication between the tubules of the epididymis and the interior of the cyst. This hole of communication they regarded as the result of rupture of the wall of the tubule into the adjacent cyst; and, in further support of this view, Curling mentions several instances in which the history of the development of such cysts seemed to indicate the probability of an accidental rupture. Curling regarded all the cysts as arising in the epididymis, whereas, as was pointed out by Hochenegg, in which view I concur, some of the large

spermatic cysts take origin in the region of the vasa efferentia. Indeed, as far as my observations go, they all do so.

In this situation the small spermatozoaless cysts are very rarely if ever found, though spermatic cysts are not uncommon.

Luschka (2), Kocher (3), Klebs (7), and Hochenegg (8) take the view first suggested by Liston, that all the spermatic cysts, or "encysted hydroceles of the testis," as they were called, are the outcome of dilatation of the tubules leading from the testis. In this I agree; I make, however, the further distinction that when the spermatic cysts are found in the upper end of the epididymis (where such cysts rarely attain any large size), they are the result of a localised dilatation of the tubules of the coni vasculosi; whereas, when the cysts, which may be large, arise between the upper end of the epididymis and the back of the body of the testis, they result from localised dilatations of the vasa efferentia, such dilatations being often accompanied by smaller dilatations of adjacent ducts and of the channels of the rête.

With regard to the mode of origin of these spermatic cysts, Kocher (10) describes them as "retention cysts;" and in support of the theory of obstruction either of the vas deferens or in the tubules of the epididymis, he mentions two cases in which he failed, even by using considerable pressure, to inject the tubules of the epididymis, and consequently the cavity of the cyst. Those who have attempted to inject the tubules of the epididymis from the vas deferens with mercury, in apparently healthy testes, would, I fear, be inclined not to lay much stress upon this statement.[1] There is, however, but little doubt that obstruction, probably of an incomplete nature, does play some part in

[1] The researches of Sir Astley Cooper, Curling, Gosselin, and Arthaud have shown that cystic dilatation of the tubules of the epididymis and vasa efferentia does not occur after either ligature or severance of the vas deferens. Since 1890 I have myself repeated these experiments, but have not yet published the results. In none of these was there anything like a cystic change induced either in the tubules of the epididymis or vasa efferentia, although these tubules and ducts did undergo enlargement which was of a uniform character, and which was the result of the retention of the seminal secretion.

Hunter, in his work on the *Animal Economy*, describes a specimen in which the vas deferens was absent nearly in its whole length; Sir Astley Cooper, Godard, Paget, Turner, Curling, and others have dissected similar cases in which the epididymis and body of testis were normal.

the production of the cystic dilatations, whether of the tubules of the epididymis or of the vasa efferentia and channels of the rête.

The evidence in favour of such a partial or incomplete obstruction is to be found mainly in the state of the tubules of the upper end of the epididymis. The epididymis (upper end) was examined in each of the specimens described in this paper, and without exception the majority of the tubules presented some indications of *chronic inflammation*. Some of the tubules were much reduced in size, the epithelium having in great part disappeared; and of the cells that remained none retained their cilia. In addition to this condition of the epithelium, the walls of the tubules were thickened and fibrous, the unstriped muscular fibres having in great part dwindled and disappeared. Other tubules were irregularly dilated, the epithelium having undergone much the same changes. The intertubular connective tissue, which in the normal state is loose and areolar, was continuous with the fibrous walls of the tubules, and thick, dense, and fibrous. In none of the tubules, however, could any evidence of their obliteration and complete closure be found. This would, perhaps, in part explain the casual relation between inflammatory conditions of the testis (possibly dependent upon gonorrhœal epididymitis) and the development of these cysts. It must, however, not be forgotten that the chronic inflammatory state of the tubules of the epididymis in these cases may be the result of pressure from the enlarging cyst or cysts, this condition following rather than preceding the development of the cysts.[1]

The seat of origin of these cysts has, moreover, been variously stated. Some have supposed that they arise from the vas aberrans Halleri; others, Giraldés (14) among them, from embryonic remains known as the organ of Giraldés; and others again, from the vasa efferentia that fail in the course of their development to strike and become continuous with the seminal tubules of the testis. Besides there being no evidence in favour of any of these views, the circumstance that the cysts

[1] Curling mentions a case reported by Mr Bryant in the *Guy's Hosp. Rep.*, 3rd s. vol. xi. p. 88, in which there were *three* distinct sacs, two of which contained spermatic fluid, while the third contained serous fluid devoid of spermatozoa.

contain spermatozoa, that in the minute structure of their walls they are like that of the walls of the vasa efferentia, and that cystic dilatations of smaller extent occur in the neighbouring ducts, render it most probable that they result from dilatation of the tubules, as above explained.

### *Subserous Cysts of the Tunica Albuginea.*

There are occasionally found small translucent cysts, sometimes extremely tense and hard on the outer surface of the body of the testicle in the superficial layers of the tunica albuginea. The fluid they contain is clear, slightly yellow, and of a serous nature. Microscopically, they are seen to be nothing more than distended lymph spaces lined by a single layer of flat endothelial cells. These cysts were first described by Sir Astley Cooper in his work on the Testis.

### *Conclusions.*

1. That the appendix of the testicle, known as the collapsed or sessile "hydatid of Morgagni," is a small, solid, corrugated body, best seen in early life; it is covered by a single layer of columnar non-ciliated epithelial-like cells, and is composed of fibrous connective tissue, in which there are numerous blood-vessels. It is not of a cystic nature, like the cysts (hydatids) found in this neighbourhood.

2. The small, sessile, or pedunculated spermatozoaless cysts, often multiple, originate as small buds or outgrowths of the tubules, which may or may not have originally been in connection with the interior of the tubules.

3. The small spermatozoa-containing cysts originate in dilatations of the tubules of the coni vasculosi.

4. The large spermatozoa-containing cysts originate in dilatation of the tubules between the testis and epididymis.

5. The small cysts on the sides (chiefly outer) of the body of the testis originate in dilatation of lymph spaces in the superficial layers of the tunica albuginea.

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## DESCRIPTION OF PLATE II.

Fig. 1. × 20. A section through the length of the "appendix" of the testicle, showing its mode of attachment to the tunica albuginea. It has a corrugated surface, and is covered by columnar epithelium, which is directly continuous with the flat endothelium covering the tunica vaginalis on the one hand, and the tunica albuginea on the other.

Fig. 2. × 18. A small, sessile, spermatozoaless cyst in the upper end of the epididymis. The cyst is lined by columnar epithelium, and occupied by granular material like coagulated albumen.

Fig. 3. Natural size. A small spermatozoa-containing cyst in the upper end of the epididymis, shown in vertical section through the epididymis E and the body of the testis T.

Fig. 4. × 35. A section through a lobule of the epididymis, showing dilatation into a cyst of one of its tubules. This cyst, of which a part only is shown, is lined by columnar epithelial cells which have lost their cilia.

Fig. 5. Natural size. A vertical section of the epididymis E and the body of the testis T. In the upper end of the former there are

numerous small cysts, the outcome of dilatation of the individual tubules. The fluid in the cysts contained numerous spermatozoa.

Fig. 6. × 50. Transverse section of two of the dilated tubules of the epididymis in the specimen from which fig. 5 was taken. They are much dilated, and the epithelial cells have lost their cilia. The coagulum in the interior is composed mainly of spermatozoa.

Fig. 7. × 45. Section of the epididymis showing irregularly dilated tubules and great increase and condensation of the intervening connective tissue. The cells lining the altered tubules are reduced in size, and are without cilia. This condition is probably the result of chronic inflammation.

Fig. 8. Natural size. Section of epididymis, spermatic cyst, and the body of the testis of the left side: (*a*) single, large, spermatic cyst pushing the epididymis (*b*) to one side; (*c*) body of the testis.

Fig. 9. Natural size. Section of the epididymis, spermatic cysts, and body of the testis of the right side: (*a*) the large cyst; (*b*) the smaller cysts; (*c*) the dilated channels of the rête testis; (*d*) the upper end of the epididymis; (*e*) the body of the testis.

Fig. 10. × 300. Section of wall of small spermatic cyst arising from dilatation of a vas efferens: (*a*) fibrous cyst wall; (*b*) columnar epithelial-cell-lining, the cells bearing no cilia, but covered on their free extremities by fine granular debris.

# ON THE STRUCTURE OF THE BONE-MARROW IN RELATION TO BLOOD-FORMATION. By ROBERT MUIR, M.A., M.D., *Senior Assistant to the Professor of Pathology, Edinburgh University*, and WILLIAM B. DRUMMOND, M.B., C.M. (PLATE III.)

(Communicated to the Scottish Microscopical Society, January 1893.)

SINCE the discovery of nucleated red blood corpuscles in the bone-marrow of adult mammals by Neumann and Bizzozero independently in 1868, this tissue has naturally been the subject of much investigation, the result of which has been to fully establish its importance in blood-formation, and to displace the old theories regarding the development of the red corpuscles. The earlier work was almost exclusively a histological study of the characters of the cells found in the marrow, and their genetic relationships to one another; and it was only after the methods of embedding in paraffin and celloidin were introduced that any satisfactory examination of its structural arrangement was rendered possible, owing to its highly cellular character and to the deficiency of supporting stroma. Even yet, however, the subject has received a comparatively small place in the literature of English histology, and in most text-books the structure of the marrow is dismissed in a few words.

In this paper we shall deal almost exclusively with the red marrow of mammals in extra-uterine life, and we shall first describe the varieties of cells found in it, discussing their relation to one another, and afterwards give an account of their arrangement in the tissue, and especially their position in relation to the blood-vessels.

The literature on the subject of the formation of red corpuscles is so extensive, and has been so fully summarised by others, that we have considered it inadvisable to give any historical account, and have only referred to some of the more important theories held on disputed points. A list of references is placed at the end of the paper.

In our research we have examined the marrow of rabbits,

dogs, and cats, as well as of the human subject, taking the marrow at different ages. We have, however, chiefly employed rabbits, as they are easily obtained, and the red marrow can be very readily removed in a piece from the long bones, no decalcifying being necessary. After the bone is carefully splintered and the fragments removed so as to expose the marrow, a portion should be separated by cutting it transversely with a razor, as the central vessels are very easily separated from the surrounding marrow if the tissue is dragged upon.

*Methods.*—Besides examining the fresh marrow without any reagent whatever, we have employed the following two fluids as media in which the marrow is dissociated, viz., a ¾ per cent. solution of sod. chlor. tinted with methyl-violet, and a 1 per cent. solution of acetic acid tinted with methyl-green. The former shows the nucleated red corpuscles well, and the general characters of the cells; the latter, the structure of the nuclei and the presence of mitotic figures. We have also employed Ehrlich's dried film method, but we found that the method[1] of fixing the films in corrosive sublimate without drying is much more suitable for marrow, as the nuclear structure is thereby much better preserved. As hardening and fixing agents we have used Müller's fluid, corrosive sublimate in saturated solution, nitric acid 5 p.c., Flemming's strong solution, and Mann's solution (acid. picric. 4, corros. sub. 15, acid. tannic 6, alcohol 100). All the tissues were embedded in paraffin, cut on the rocking-microtome, and the sections fixed to the slide by Gulland's water method. On the whole, we found corrosive sublimate the most useful fixative for this tissue. Nitric acid brings out the characters of the nuclei with great clearness. It is unnecessary to enumerate all the stains employed. Biondi's stain, and the triple stain of hæmatoxylin, saffranin, and orange, gave specially good results. In employing the latter the sections are stained for about half a minute in Ehrlich's acid hæmatoxylin, and are then put through acid and alkali in the usual way. They are then stained for about three minutes in a moderately strong solution of saffranin in equal parts of alcohol and water. They are then washed thoroughly in water or in weak alcohol, and placed in a strong watery solution of orange for about two minutes. More recently we have obtained very good results with Heidenhain's hæmatoxylin iron-alum method.[2]

[1] This *Journal*, 1892, p. 394.
[2] Kölliker's Festschrift. Würzburg, 1892, p. 118.

## Cellular Elements of Marrow.

In studying the cells present in the bone-marrow it is important to distinguish those which properly belong to it, and which do not appear in the general circulation, from the cellular elements of the blood flowing through it. The former may be conveniently divided into three groups, viz., marrow-cells; erythroblasts, or the nucleated antecedents of the red corpuscles; and giant-cells. These last are to be sharply distinguished from the multi-nucleated osteoclasts, which have no connection with the blood-forming tissue.

(a) *Marrow-cells*.—These are spherical colourless cells, which are present in large numbers, and together make up a considerable proportion of the substance of the marrow. The largest are generally about 16 $\mu$ in diameter, and the majority are 12–14 $\mu$. They are of two varieties—the finely granular and the coarsely granular (eosinophiles).

The finely granular or "ordinary small marrow-cells" are always distinctly more numerous than the eosinophile forms, though the proportion varies in different animals and at different ages, the eosinophiles being sometimes relatively few in number. They possess a single large nucleus, which is rounded, oval, or indented at the side so as sometimes to have a lobate or horse-shoe shape (fig. 1). The nucleus, which is relatively poor in chromatin, has a distinct nuclear membrane, and contains a fine nuclear network, often appearing imperfect, with some scattered fragments of chromatin, and one or more nucleoli, which are coloured red with Biondi's stain and with the hæmatoxylin-saffranin combination. These nucleoli are rounded, oval, or irregular in shape, though sometimes of distinctly dumb-bell form. The protoplasm of these marrow-cells is bounded by no distinct membrane, and contains exceedingly minute eosinophile granules like the finely granular leucocytes of the blood. The protoplasm stains somewhat with nuclear stains, as can be well seen by examining in neutral salt solution tinted with methyl-violet, or in sections stained with saffranin, in which it is more deeply tinted than the general nuclear substance (fig. 4).

These cells multiply by mitosis, and we have been able to follow every stage in the process (fig. 1, *b*). The nucleus at the beginning of the process is generally spherical, but we have seen the chromatin becoming arranged into threads, and the membrane disappearing even when the nucleus had the indented form. Mitotic figures are especially numerous in young animals, but are also found in adults.

We have seen appearances which are very suggestive of the occurrence of direct division also. The nucleus may sometimes appear constructed into two halves, as in fig. 1, *c*; and as it is exceedingly rare to find a cell with two similar nuclei, it is only reasonable to suppose that division of the cell follows. Such appearances have been found by us only in young animals; and as they are very rare in proportion to the number of mitotic figures, the process cannot be a common one. Apparently, also, division of the nucleus by mitosis may be completed before the division of the cell takes place (fig 1, *d*).

The eosinophile or coarsely granular marrow-cells also possess a single nucleus which is similar in structure to that described above. They also multiply by mitosis. In short, the two varieties differ only in the character of their granules (fig. 1, *e f*).

It will thus appear from the above description that in the structure of the nucleus and in its varieties of form, as well as the character of the protoplasm, the marrow-cells correspond with the leucocyte class, but this relationship will be discussed later.

(b) *Erythroblasts.*—We use this term in its widest sense to include all the nucleated antecedents of the red corpuscles, both coloured and colourless. The name as first used by Löwit was applied to the colourless predecessors of the nucleated red corpuscles, but it is more convenient to employ it in the manner indicated, and speak of colourless and coloured erythroblasts.

The typical *nucleated red corpuscle* or coloured erythroblast is a cell with special characters, which mark it off distinctly from the marrow-cell. Some of them are considerably larger than the ordinary red corpuscles: in the rabbit's marrow, for example, some may reach 12 $\mu$ in diameter, others are of the same size as the red corpuscles, and all intermediate sizes are present.

The perinuclear portion is entirely free from granules, has a distinct outline, and is coloured with hæmoglobin, as can be seen in the fresh condition as well as by the employment of staining reagents. The nucleus is quite circular, lies in the centre or towards the periphery of the cell, and is characterised by its richness in chromatin, and consequent intensity of staining. Its proportionate size varies in different cells, being greater in the larger cells, and relatively smaller and more condensed in the smaller forms. In the larger cells, which are very faintly tinted with hæmoglobin, the nuclear chromatin can be very clearly seen to be arranged as a thick regular network with slight thickenings at the nodal points, so as sometimes to give the appearance of small round granules scattered through the nucleus. The nuclear membrane is not thicker or more distinct than the threads of the network, and we have not been able to detect the presence of a nucleolus (figs. 2 and 4). In the smallest nucleated red corpuscles, which are well coloured with hæmoglobin, the nucleus is small and condensed, its diameter being often less than half that of the cell, and has a quite homogeneous appearance. It stains very deeply with nuclear stains, retaining saffranin with even greater tenacity than the threads of mitotic figures, as Van der Stricht points out.

These two types form the extremes of a series between which all intermediate forms may be found. The youngest cells (*i.e.*, those farthest removed from the non-nucleated condition) are the largest, have a proportionately small amount of protoplasm tinted with hæmoglobin, and a large nucleus with distinct network. Numerous mitotic figures are seen in these cells, the figures being small and the threads closely arranged. As the cell becomes older the nucleus becomes denser and ultimately homogeneous, and the hæmoglobin more abundant, diminution in size taking place by successive divisions of the cell. Probably, as Howell says, division may take place at any stage till the homogeneous condition of the nucleus is reached. We have seen mitosis in cells quite deeply coloured with hæmoglobin.

Are there colourless erythroblasts? On this question there has been considerable discussion, but the great weight of opinion is that there are. We have already mentioned that the youngest nucleated red corpuscles are very faintly tinted with hæmoglobin,

and there are certainly cells of precisely the same structure in which we can detect no hæmoglobin. Whether it is absolutely absent we cannot say. As the hæmoglobin is produced by the vital action of a cell specialised for the purpose, it is not necessary, on theoretical grounds, that some hæmoglobin should be present that more may be produced, though some writers speak as if it were. The question, therefore, is not of great importance, unless in relation to the possible connection of the nucleated red corpuscles with marrow-cells; and as there are among the former all stages down to the almost colourless condition, the presence of hæmoglobin cannot be used as a means of defining the erythroblast group, unless there are other corresponding characteristics. And as there are colourless cells of the same structure as the young nucleated red corpuscles, we consider it quite correct to call them colourless erythroblasts.

*Manner of disappearance of the nucleus of the nucleated red corpuscle.*—This is another point on which there has been and still is great dispute. It is unnecessary to state the opinions held by various observers. As indicating the difficulty of the problem, it is sufficient to state that as many hold that the nucleus atrophies and gradually disappears, as that it is extruded from the cell. We have already described the change which the nucleus undergoes as the cell becomes older, and the number of nucleated red corpuscles with the nucleus in the small homogeneous condition is a relatively large one. We have, however, searched in vain for cells with the nucleus so small that it could be described as just about to disappear, and must consider that such would be easily found if the nucleus were lost by atrophy. On the other hand, in sections as well as by the other methods of examination, we find free nuclei of nucleated red corpuscles (the nuclei can easily be recognised by their characters), and we can scarcely look upon this as accidental. We have, however, been unable to definitely determine the ultimate fate of the nucleus, though probably it is broken down and disappears in the marrow. The theory of Rindfleisch (1) that it carries with it a small rim of protoplasm and forms another nucleated red corpuscle, is exceedingly improbable, on account of its homogeneous and apparently degenerated condition when it leaves the cell. Omar Van der Stricht (27 & 28) states that the extruded nuclei

are taken up by the giant-cells and other cells and then undergo disintegration, but we have been unable to satisfy ourselves of the correctness of this view. That the nucleus does not enter the general circulation we think is quite certain, as there is no structure in the blood which at all resembles it; and the theory of Afanassiew (6) and others, that it becomes a blood-plate, must be looked upon as quite erroneous.

*Relation of Erythroblasts to other Cells.*—Without entering at all fully into the extensive literature on this subject, it may be instructive to mention some of the chief theories held by different writers. Löwit (7, &c.) holds that there are colourless erythroblasts which become nucleated red corpuscles, and which form a distinct class of cells, and differ from the leucocytes in the structure of the nucleus and in the mode of division, the erythroblasts dividing by mitosis and the leucoblasts by direct division. Denys (10) agrees with Löwit as to the distinctness of the two classes of cells, but bases the distinction on the characters of the nucleus and protoplasm only, as the leucoblasts also multiply by mitosis, and this last must now be held to be completely proved. Bizzozero (24) finds that the erythroblasts are a distinct class of cell, but that all contain hæmoglobin; whilst Van der Stricht (27 & 28) agrees with Denys, and calls the marrow-cells leucoblasts. Howell (21) maintains that the marrow-cells are embryonic cells, whose function is to multiply by division and become nucleated red corpuscles. During the successive mitoses the cells become smaller, and pass from the type of the marrow-cell to that of the nucleated red corpuscle. Howell does not describe the marrow-cells as being related to leucocytes at all. Müller (17) would place most of the marrow-cells in the leucocyte class, but considers that there is present a common ancestor to the two classes—leucoblasts and erythroblasts. It will thus be seen that the majority of these authors agree in placing erythroblasts as a distinct class, not related to others.

Howell's theory, which is based upon the supposed existence of intermediate forms between marrow-cells and erythroblasts, is worthy of careful consideration. Now the following facts, in the first place, are in favour of the marrow-cells being placed in the leucocyte class. The characters and the various forms of

their nuclei closely correspond with those of the leucocytes of the blood. Further,—and this appears a point of importance,—the eosinophile marrow-cells multiply by mitosis and produce smaller cells, which can become nothing else than the eosinophile leucocytes of the blood. Again, in the marrow of birds the parenchyma is completely shut off from the venous capillaries (in which the erythroblasts lie, *v. infra*), and the cells of the parenchyma are undoubtedly leucocytes, which are evidently the homologues of the marrow-cells of mammals. And we have noticed that in certain parts of the mammalian marrow, where the parenchyma is more completely differentiated than usual from the vascular channels, the cells in the former are almost exclusively marrow-cells. We must therefore consider that the marrow-cells are a class of the leucocyte order. There still remains the possibility to be considered, that *some* become differentiated into the erythroblast class—which closely resembles Müller's theory, that there is a common ancestor, or, in other words, that differentiation into erythroblasts and leucoblasts is still going on in the marrow in extra-uterine life. From the description given above, which closely agrees with that given by almost all writers on the subject, it will be seen that a typical marrow-cell differs in almost every particular from a nucleated red corpuscle; and in the case of the great majority of cells found in the marrow, there is no difficulty whatever in referring them to one of the two types. There are, however, a few cells to be found which have somewhat intermediate characters. These cells are rather smaller than the ordinary marrow-cells, have a rounded nucleus with more abundant chromatin, and the protoplasm may show a faint granularity. We have studied these cells in a great variety of ways, and have had great difficulty in coming to a conclusion regarding them. It seems on the whole likely, however, that they are only apparently intermediate, and that some may be small marrow-cells which have just passed out of the mitotic stage, whilst others may be larger forms of erythroblasts. It is a point of great importance, that in all the erythroblast series the nucleus is of one definite type, though it undergoes condensation, whilst the type of the nucleus of the marrow-cell is also distinct, and we would expect much more definite evidence if there were

a regular transition from one to the other. Taking, therefore, all the facts into consideration, we believe that the two classes are distinct, and that the marrow-cells belong to the leucocyte order.

We may mention here that the distinction between the two types of nuclei comes out most clearly when the cells are examined in the methyl-violet salt solution, or in sections fixed with nitric acid or with Flemming's solution, and stained in saffranin. In the double nuclear stain with hæmatoxylin and saffranin the nuclei of the erythroblasts are red, while those of the marrow-cells are blue, though this distinction is not an absolute one, as it depends upon the time allowed for staining.

(c) *The giant-cells* are cells of remarkable character, and form a striking feature in a section of marrow. They are amongst the largest cells in the body, many measuring over 60 $\mu$ in diameter. We may again repeat that they belong properly to the hæmopoietic tissue, and have no relation or resemblance to the giant-cells of bone or osteoclasts. They possess, as a rule, a single nucleus of peculiar structure. It is of various shapes, but may be said to be either markedly lobulated or arranged in a basket-like manner with a space in the centre ("endoplasm") which communicates by apertures in the nucleus with the surrounding protoplasm ("exoplasm"), fig. 4. In many cells there are apparently smaller detached nuclei, but these, if examined in successive sections, are found to be merely lobules of the single large nucleus. The nucleus in the resting condition, as seen in the great majority of the giant-cells, is relatively poor in chromatin, which is arranged, much as in the marrow-cells, as a fine network, chiefly, we believe, on the surface of the nucleus, with thickened nodes here and there. It also contains several nucleoli, which can be easily distinguished by their red colour with Biondi's stain. Most of these cells have a relatively large amount of protoplasm, which is faintly granular, and takes the acid aniline stains rather more deeply than the protoplasm of the small marrow-cells. The coarse eosinophile granules are never seen in the giant-cells.

There are other giant-cells of smaller size, which almost form a separate class, in which the protoplasm is very small in amount, or apparently absent, and the nuclear chromatin arranged in irregular threads or masses. These are probably

giant-cells in process of degeneration, as they cannot, we think, represent phases in the division of the cell. A further stage in degeneration would appear to be represented by smaller rounded or oval masses, homogeneous in appearance, which stain very deeply, and in the hæmatoxylin-saffranin stain take the red colour.

The giant-cells have, during recent years, been the subject of considerable investigation by various observers, but scarcely any two have been agreed regarding their function, and their mode of formation and multiplication. Space forbids us to discuss all the theories. As regards their mode of division, indirect fragmentation has been described by Arnold (13) and Werner (14), direct fragmentation by various observers, direct division by Howell (22) and others, "stenosis" (a sort of endogenous formation of cells by budding) by Denys (11), multiple mitosis by Denys and Van der Stricht (21), whilst ordinary bipolar mitosis has also been described. The only method which we have seen with certainty is mitosis, though cells in the process are comparatively rare. Most of the examples we have seen were the earlier phases, but one or two later showed, we believe, pretty conclusively that the mitosis was of the multiple type. Ordinary mitotic division into two we have never seen. We have found only doubtful instances of direct division—not as are figured by Howell and Van der Stricht, which appear pretty conclusive. We have found no evidence of the other methods.

It may be mentioned here that Heidenhain (29) has announced the discovery of multiple centrosomes in these cells. He does not describe his method, but promises a further communication on the subject.

The giant-cells are, we believe, formed from the ordinary marrow-cells, and in young animals all the stages of the process can easily be followed (fig. 3). The nucleus becomes enlarged and furrowed at one point, and then with further enlargement more furrows appear, so as to produce a number of thick, blunt lobules. Ultimately, by extension of the process, the typical basket-shape is reached. During the process the structure of the nucleus undergoes little alteration, though the nucleoli greatly increase in number.

Regarding their function very little has been established.

They have been supposed by some to produce erythroblasts, by others merely to reproduce marrow-cells, by Van der Stricht to absorb the nuclei of the nucleated red corpuscles, by Howell to have chiefly a nutritive function, &c. Their presence, where the mammalian non-nucleated red corpuscles are being formed, (*e.g.*, also in the embryonic liver) would seem to point to their being connected with the process, but this has not been proved. Or, on the other hand, they may merely represent a peculiar form of growth and division of cells under certain conditions of nutrition. We intend to study this subject more thoroughly, and hope to make a further communication.

## Arrangement of Cells in the Marrow, and relation to Blood-vessels.

It will greatly facilitate the description of the marrow of mammals if we first briefly describe the arrangement in the marrow of animals with nucleated red corpuscles, taking birds as examples. The marrow of birds may be said to consist of a cellular parenchyma freely traversed by vessels of peculiar character. The arteries lead down to capillaries of ordinary width, called arterial capillaries, which discharge their blood into wide venous capillaries in communication with the veins. These venous capillaries have a lining of several layers of young spherical red corpuscles which are stationary, only the central or axial portion being filled with a flowing stream of ordinary red corpuscles. The young red corpuscles multiply by mitosis, and as they acquire the adult characters pass into the circulation. The parenchyma, which is separated from the venous capillaries by a very thin endothelial lining, is composed of leucocytes with a very scanty reticulum. These leucocytes divide in the same way and pass through the capillary walls to the blood. There is therefore in the marrow of birds a closed vascular system which has a hæmopoietic function, with the parenchyma between.

In the marrow of mammals also it is convenient to speak of parenchyma and vessels, though the distinction between them is only partially preserved. The supporting stroma is very small

in amount, probably smaller than in any other organ in the body. At the periphery of the marrow it is arranged as one or two layers of connective-tissue corpuscles, with fibrils between, and from these delicate filaments, with nuclei at intervals, pass inwards and are connected with the blood-vessels, fat-cells, &c. In the centre of the marrow there is generally a single artery and a vein of much larger diameter. The artery gives off small branches, which terminate in ordinary capillaries, which may be conveniently called arterial capillaries. If these be carefully followed they can be seen to terminate in comparatively wide vascular channels, which may be called venous capillaries, though they have not a complete endothelial lining. The arterial capillaries are comparatively few in number, and their total transverse diameters must form a very small fraction of those of the venous channels. The greater part of the marrow seen on section is made up of the venous capillaries and the parenchyma, with fat-cells scattered in it fairly regularly, though these are generally more abundant around the central vessels. The venous channels are of comparatively large size, their diameter often being equal to that of eight or ten red corpuscles, and run in a somewhat tortuous manner. They are generally somewhat irregular in shape on section, and are bounded in part only by endothelial cells; in part also by fat-cells and by the marrow parenchyma, with which there is direct communication. They open into the central thin-walled vein often by comparatively small apertures, and sometimes many may be seen to become confluent first.

The marrow parenchyma which forms the general groundwork is composed for the most part of marrow-cells, with a very small amount of supporting connective-tissue fibres. There is not, however, a distinct separation between it and the vascular channels, and erythroblasts and ordinary red corpuscles are also seen between the marrow-cells in the parenchyma. The marrow-cells may also be seen at the margin of the blood-stream in the venous capillaries. The erythroblasts tend to be arranged in small groups, which often lie at the periphery and in the corners of the venous capillaries in direct contact with the red corpuscles, but they are also found in the parenchyma (fig. 5), and they never form a complete layer as is found in the venous capillaries

of birds' marrow. At certain places one may often see a venous capillary incompletely bounded by an endothelial lining, and immediately on the other side of the endothelium red corpuscles, which are lying between the marrow-cells of the parenchyma in communication with another venous capillary. The degree to which the parenchyma is cut off from the blood in the venous capillaries varies much at different parts and in different conditions. The two parts are generally most distinct at the margin of the red marrow where it is passing into the yellow marrow, whereas in young marrow, when active blood formation is going on, it is often difficult to make out any line of separation, and the red corpuscles are seen in what are simply channels between the marrow-cells, &c. (fig. 6).

The giant-cells properly belong to the parenchyma, and are scattered fairly uniformly through it, though they are more abundant at the peripheral part of the section. Very often a giant-cell has a group of marrow-cells in contact with it, though erythroblasts also may lie around it, and sometimes it may be seen at one part to lie directly in contact with the blood in the venous capillaries, there being no trace of an endothelium between them.

The eosinophile marrow-cells are scattered amongst the ordinary marrow-cells, often occurring in little groups, and appear to have no special arrangement. They are more numerous in the marrow of an adult rabbit than in that of the young animal, and more abundant in some animals than in others, *e.g.* in rabbits than in dogs.

From the above description it will appear at once that the circulation through the marrow must be exceedingly slow. We have mentioned the relatively small number of arterial capillaries and the relatively small size of their lumen as compared with the venous channels; and as these regulate the amount of flow through the tissue, the movement of corpuscles in the latter will be a comparatively gradual one. And we are not certain that all the red corpuscles seen in the parenchyma are really in motion. Some, at least, have probably just lost their nuclei, and have not yet appeared in the circulation.

We may now consider the bearing of these peculiarities in the structure and arrangement of the marrow on the two facts, viz.,

first, that normally no nucleated red corpuscles are present in the general circulation; and secondly, that after severe bleeding they may appear. As has been pointed out, they are not shut off in any way from the circulating blood, and, so far as the microscopic appearances are concerned, might be supposed to be free to enter it. That they do not do so is probably due to an amount of cohesiveness amongst the cells to one another. This has been practically demonstrated by Denys (10) in the case of birds. By careful injection with Prussian blue, he found that the material injected passed along the venous capillaries and was found amongst the adult red corpuscles which lie in the centre, but not amongst the young forms (erythroblasts) which form a lining to the channels. Supposing, then, that in the marrow of mammals the nucleated red corpuscles have a certain cohesiveness which keeps them in position, aided, no doubt, by the small amount of movement of the red corpuscles at the periphery of the stream, another question arises, viz., do the corpuscles pass into the blood-stream immediately after losing the nucleus, or do they undergo some change in their physical properties before doing so? We think the latter supposition probable on general grounds and for the following reasons. In normal blood all the red corpuscles stain alike, but one of us (20) has observed, that, after bleeding animals (and the same thing was noticed in the human subject after hæmorrhage), not only did nucleated red corpuscles appear in the circulation, but also some of the red corpuscles stained more deeply with methyl-blue than the ordinary red corpuscles, which have merely a pale green tint; *i.e.*, they were less purely oxyphile, and in this they resembled the perinuclear portion of the nucleated red corpuscles. We also found that in staining sections of marrow with a double contrast of rubin and orange, the red corpuscles in the veins took the orange much more deeply than many of those between the marrow-cells and at the periphery of some of the venous capillaries, thus indicating a similar difference in their quality.

The condition which most probably obtains would therefore appear to be the following. The nucleated red corpuscles are in free communication with the blood-stream but do not enter it in normal conditions, being retained in position by their mutual cohesiveness. When they lose their nucleus they still

retain this property to a certain extent and remain in position, gradually acquiring the physical properties of the adult corpuscles, and then pass into the flowing current.

After severe hæmorrhage there occurs a dilution of the blood so far as the red corpuscles are concerned, and therefore a loosening, as it were, of the corpuscles in the vascular channels of the bone-marrow (in sections of normal marrow the corpuscles are seen closely packed together); and it is quite intelligible that by this process of dilution the normally stationary corpuscles, probably both nucleated and non-nucleated, may tend to become separated and to enter the circulating blood. We may, in fact, look upon the richness of the blood in corpuscles as determining the stability of the cellular arrangement in the marrow. And further, poverty in corpuscles, besides inducing certain cells to appear in the circulation, may also act as a stimulus to other cells to proliferate, as it is thoroughly well established that the effect of hæmorrhage is to greatly increase the number of nucleated red corpuscles in the marrow, and also the number of mitotic figures amongst them.

This mechanism is most easily understood in the case of the marrow of birds, in which, as already described, there is in the venous capillaries a central moving column of blood surrounded by layers of erythroblasts. It is quite evident that if the circulating blood become poorer in red corpuscles the superficial layer of erythroblasts will be freer from contact, and this altered condition may induce proliferation. Reasoning from analogy and from the facts observed, we believe that the same explanation is applicable in the case of mammals.

We have much pleasure, in conclusion, in recording our thanks to Professor Greenfield, in whose laboratory the work was done, for the facilities afforded.

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(9) Löwit, "Die Anordnung und Neubildung von Leukoblasten und Erythroblasten in den Blutzellen bildenden Organen," *Arch. f. mikr. Anat.*, 1891, p. 524.

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(13) Arnold, "Weitere Beobachtungen über die Theilungsvorgänge an der Knochenmarkzellen," *Virchow's Archiv*, Bd. 97, p. 107.

(14) Werner, *Virchow's Archiv*, Bd. 106, p. 354.

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## DESCRIPTION OF PLATE III.

Fig. 1. *a*, ordinary marrow-cells, showing variations in form of nucleus. *b*, ordinary marrow-cells in various stages of mitotic division. *c*, marrow-cell in which the nucleus is apparently divided into two. *d*, marrow-cell with two nuclei, evidently the result of mitosis. *e*, eosinophile marrow-cells. *f*, eosinophile marrow-cell in mitosis.

From film preparations fixed in corrosive sublimate. Hæmatoxylin and eosin. All are from rabbit's marrow, with the exception of *c* and *d* which are from the marrow of a kitten. *c* and *d* are reproduced from a photograph.

Fig. 2. Erythroblasts from marrow of rabbit. *a*, colourless erythroblast. *b*, coloured erythroblast, protoplasm very feebly tinted. *c*, the same, in mitosis. *d*, small coloured erythroblast with reticulum of nucleus well marked. *e*, the same, with small homogeneous nucleus. *f*, small, well-coloured erythroblasts in mitosis. 'Corrosive-film.' Hæmatoxylin and orange.

Fig. 3. Shows different stages in development of giant-cells from the ordinary small marrow-cells.

From a section of rabbit's marrow. Corros. sublim. Hæmatoxylin and saffranin.

Fig. 4. Portion of a section of rabbit's marrow showing the character of the nuclei of the various cells. *a*, giant-cell. *b*, marrow-cells. *c*, erythroblasts. *d*, erythroblast in mitosis. *e*, ordinary multi-nucleated leucocyte of blood. *f*, connective-tissue corpuscle.

Fig. 5. Portion of section of rabbit's marrow, showing general arrangement of the tissue. *a*, venous capillary or channel. *b*, parenchyma. *c*, fat-cells. *d*, eosinophile cells. Two giant-cells are shown. The nuclei of the erythroblasts are red, those of the marrow-cells are blue.

Corros. sublim. Hæmatoxylin, saffranin, and orange.

Fig. 6. Portion of marrow of young rabbit, showing its very cellular character and the arrangement of the cells. The different cells may be recognised from the previous figures: *a*, giant-cell probably undergoing degeneration; to the left is seen a small giant-cell. The red corpuscles are seen lying in channels amongst the cells.

# THE PHYSIOLOGICAL CHARACTERS OF CARCINOMATA (PRIMARY AND SECONDARY). By H. J. WARING, M.B., B.S., B.Sc., F.R.C.S.

(From the Pathological Laboratory of St Bartholomew's Hospital.)

THE literature of the carcinomata contains very few accounts of the chemical and physiological characters of malignant neoplasms.

Foy, writing in 1828,[1] and Lobstein in 1829,[2] published the results of their analyses of cancerous tumours. In 1838[3] Müller gave a fairly clear account of the chemical composition of some varieties of carcinomata which he had examined. Lhéritier, in his treatise on chemical pathology, published in 1842,[4] records the work of Baudrimont, Collard de Martigny, and several other investigators upon the chemistry of scirrhous and encephaloid carcinomatous tumours. Heyfelder in 1846[5] published the results of analyses made by Bibra and Gorup. All these authors give imperfect analyses of different cancerous tumours. They did not, however, in many cases clearly recognise the variety of tumour upon which they were experimenting. In many cases the cancerous material was taken from the liver, and then it is not always clear whether they were dealing with a primary neoplasm of that viscus, or with secondary carcinomatous or sarcomatous deposits, which had arisen as the results of a primary neoplasm in some other part of the body. At that time, also, the exact differences between sarcomata and carcinomata had not been clearly recognised. Since then other analyses have been made by other investigators, which have given more correct and reliable chemical results. None of these authors, however, has given any account of the presence or absence of any ferments which may exist in these growths, or has determined their physiological properties.

The following investigations have been carried out with the object of determining whether or not the cells of carcinomatous growths produce, by their metabolism and vital activity, ferments similar to those which are produced by the epithelial cells of the organ in which the primary cancerous growth takes its origin, or whether they produce substances which are peculiar

[1] Foy, *Archives générales de Médecin*, Tom. xvii., 1828.
[2] Lobstein, *Traité d'anatomie pathologique*, 1829, Tom. i. p. 426.
[3] Müller, *Ueber den feineren Bau der Geschwülste*, 1838, p. 24.
[4] Lhéretier, *Traité de chemie pathologique*, 1842, pp. 683–688.
[5] Heyfelder, *Oppenheim's Zeitschrift*, 1846.

to themselves, or if they have definite physiological characters which are the same as or different from those of the normal epithelium.

Three cases of carcinoma of the pancreas, each with secondary deposits in the liver, and two cases of carcinoma of the stomach, have been examined. In all the cases the cancerous material was removed from the cadaver some hours after death (varying from twelve to twenty-four).

### A. Primary Growths.

*Case* I.—Carcinoma of the head of the pancreas, with numerous secondary deposits throughout the liver. No deposits in any other organ.

(1.) A portion of the carcinomatous mass was taken quite free from any of the surrounding uninvolved pancreatic tissue, and separated as far as possible from any adherent connective tissues, and then minced in a sausage-mincing machine. This was placed in a quantity of pure glycerine, in which it was allowed to remain for seven days, the mixture being well shaken up each day so as to expose fresh surfaces of the carcinomatous tissues to the action of the glycerine. At the expiration of this time the mixture was filtered, and the filtrate retained for examination.

Nine test-tubes were now taken and labelled A. B. C. D. E. F. G. H. and I. Into each was introduced a small quantity of the filtrate.

| | | | |
|---|---|---|---|
| To | A. | was added | fibrin and a few c.c. of distilled water. |
| „ | B. | „ | white of egg „ |
| „ | C. | „ | fibrin and soda bicarb. 1 per cent. |
| „ | D. | „ | white of egg and soda bicarb. 1 per cent. |
| „ | E. | „ | fibrin and hydrochloric acid ·2 per cent. |
| „ | F. | „ | white of egg + 0·2 per cent. hydrochloric acid. |
| „ | G. | „ | boiled starch and distilled water. |
| „ | H. | „ | olive oil. |
| „ | I. | „ | milk. |

These test-tubes were then placed in an incubator kept at a temperature of 36° C. and left for a few hours. On examination after six hours the following changes were noticed.

A. The flakes of fibrin were much eroded, smaller, and in great part had disappeared. The fluid contained considerable quantities of peptone.

B. Albumen of white of egg partially converted into peptone. Still some albumen, which coagulated on heating and had other characters of egg albumen.

D. Much peptone present. Small quantity of egg albumen.

E. Fibrin somewhat swollen up, otherwise little changed. No peptone. Some acid albumen.

F. Egg albumen still present. No peptone. Some acid albumen.

G. Fluid contains considerable quantity of a substance which precipitates copper oxide from Fehling's solution. This is grape sugar. Still some free starch, which gives blue coloration with iodine.

H. Fluid quite opaque. Acid in reaction. Under the microscope, oil was seen to have been emulsionised.

I. Milk curdled a few minutes after the glycerine extract was added.

This series of experiments shows that the primary carcinomata of the pancreas contain substances which have the property of D. converting proteids into peptones.

D. „ starch into grape sugar.

D. emulsifying and splitting up fats.

D. curdling milk.

A further portion of the glycerine extract was taken and treated with absolute alcohol. This gave rise to the formation of a precipitate. This was collected and dried at a low temperature, and then dissolved in a 1 per cent. solution of sodium bicarbonate.

Upon the food stuffs, this solution has a well-marked peptonising action on the proteids and a diastatic action on starchy substances. Upon fats it had no effect.

A portion of the growth was treated by Kühne's method for obtaining trypsin. In this way a substance of a proteid nature was obtained which had a strong peptonising action upon proteids in an alkaline solution (1 per cent. sodium carbonate). In an acid medium the substance was inert. Boiling for a short time completely destroyed its active properties.

From these experiments it may be concluded that a ferment having all the properties of trypsin is present in the carcinomatous growth of the pancreas. Precipitation of the glycerine extract with lead acetate separated a substance which possessed the power of rapidly converting soluble starches into sugars. The activity of this substance was soon destroyed by boiling. Hence it can be assumed that there is present in the carcinomatous growths of the pancreas a ferment which is identical with the amylopsin which is found in the normal gland-tissue and secretion.

The presence of a milk-curdling ferment was shown by test-tube I.

As regards the fat-emulsifying substance in the normal pancreas, the steapsin cannot be separated by glycerine. In the case of the carcinomatous, we have seen that a fat splitting and emulsifying substance was present in the glycerine extract. This may be explained by the fact that the carcinomatous tissue contained a considerable amount of juice which might easily have passed through the filter and so carried the steapsin with it.

A similar series of experiments was carried out in cases II. and III., and in both identical results were arrived at.

B. *Case* I.—Secondary deposits in the liver. Several masses of the neoplasm in the liver were taken and quite freed from adherent liver substance and connective tissue. The material so obtained was then minced and treated with pure glycerine in the same way as the primary growth. A series of experiments exactly similar to those done in the case of the primary growth was carried out. These gave rise to identical results, all the ferments which were discovered in the primary growth being found in the secondary deposits. The fat splitting and emulsifying action was more powerful than in the primary growth. This is probably to be explained by the fact that the secondary deposit was obtained from the liver.

With the secondary growths obtained from cases II. and III. similar results were recorded.

Portions of the primary and secondary growths were examined with the microscope, and in all cases granules were seen scattered through the protoplasm of the carcinomatous cells; these were comparable to those found in the healthy secreting pancreatic cells.

Therefore, from the above series of experiments it may be concluded that—

(1.) In primary carcinomatous growths of the pancreas there are present the same physiological ferments as in the normal healthy gland, viz.—

*a*, Trypsin; *b*, Amylopsin; *c*, Steapsin; *d*, Milk-curdling ferment.

(2.) That the secondary deposits occurring in the liver contain the same physiological ferments as the primary growths, and hence the same as the normal healthy gland from the epithelium of which the primary growths have been derived.

## Carcinoma of the Stomach.

*Case* I.—In this case the wall of the stomach a short distance from the pylorus was occupied by a softish mass of carcinoma.

Part of this was removed and separated as completely as possible from any uninvolved mucous membrane, and also from any of the surrounding muscular wall of the organ. The material so obtained was then thoroughly minced and mixed with pure glycerine. One week afterwards the mixture was filtered and the filtrate retained and submitted to the following experiments:—

*Series* 1. A portion of the filtrate was placed in test-tubes labelled A. B. C. D. E. and F.

To A. was added fibrin and distilled water.
„ B. „ „ and ·2 per cent. hydrochloric acid.
„ C. „ white of egg and distilled water.
„ D. „ white of egg and ·2 per cent. of hydrochloric acid.
„ E. „ boiled starch and distilled water.
„ F. „ olive oil.
„ G. „ milk.

These tubes were placed in an incubator kept at a temperature of 36° C. and left there for six hours.

On examination they presented the following appearances, viz.,—

A. The contents were unchanged.

B. The fibrin had disappeared, and in the tube considerable quantities of peptone were detected.

C. Contents unchanged.

D. Egg albumen converted into peptone.

E. Contents unchanged.

F. Ditto.

G. A few minutes afterwards the milk was curdled.

These experiments show that in the glycerine extract there is a substance which converts proteids into peptones in the presence of dilute hydrochloric acid, and also a substance which possesses the power of curdling milk.

*Series* 2.—Von Wittich's method of separating pepsin was adopted. To the glycerine extract absolute alcohol was added. This gave rise to a precipitate which was collected and then dialysed. By this means any salts or peptones present were got rid of. The substance so obtained was divided into portions and placed in test-tubes labelled A. B. and C.

To A. was added fibrin and distilled water.

„ B. „ fibrin and ·2 per cent. hydrochloric acid.

„ C. „ starch.

In D. was placed fibrin and ·2 per cent. hydrochloric acid. These were placed in an incubator at 36° C., kept there for six hours and then examined.

In A. Contents unchanged.

„ B. Fibrin disappeared. Fluid contains considerable quantity of peptone.

„ C. Contents unchanged.

„ D. Fibrin swollen. Some acid albumen present.

These experiments point to the presence in the cancerous material of a substance which has all the characteristics of pepsin.

In another similar series of experiments carried out with cancerous material obtained from another case of carcinoma of the stomach, identical results were arrived at.

From these experiments it may be concluded that in the carcinomatous growths commencing in the epithelium of the mucous membrane of the stomach there is present the ferment pepsin and also rennin.

I have been unable as yet to obtain any specimen of secondary growths coming on as a result of a carcinoma, primary in the mucous membrane of the stomach, hence it has not been possible to prove that the cells of these secondary growths

possess the same property of producing the ferments pepsin and rennin which are the normal products of the cells from which the pathological formation has been derived.

From the results of these series of investigations it can be reasonably concluded that—

(1.) The cellular elements of the primary and secondary carcinomata of the pancreas possess the property of producing, as a result of their growth and metabolism, the same or similar ferments, viz., trypsin, amylopsin, steapsin, and rennin, as are produced by the normal secreting cells of the gland.

(2.) The primary carcinomata of the stomach produce the ferments pepsin and rennin, which are the normal physiological products of the secreting cells of the mucous membrane of the stomach. Taking the pancreas and stomach as typical examples of secreting glandular structures by analogy, it may be assumed, with a fair amount of probability, that when carcinomatous growths start from a glandular structure, the epithelial elements of these growths will, by their growth and metabolism, produce the same or similar physiological products as are formed by the gland cells when in their normal state.

If these conclusions hold good for all carcinomatous growths, it will be difficult to believe in the sporozoa theory of cancer, unless it can be shown that the parasites act in one of the following ways, viz.,—

(1.) That by their presence in the cells whence a carcinoma takes its origin, they so stimulate the reproductive elements of the cells, as to give rise to the formation of a large mass of cells which grow and divide rapidly; and in which the protoplasm still retains the physiological properties of the parent cells from which it has been derived.

(2.) That the cancerous cells themselves consist chiefly or entirely of sporozoa and their products, and that their sporozoa acquire the physiological properties of whatever epithelium they happen to locate themselves. The second possibility is very unlikely, and the first is difficult to accept unless it can be shown that their so-called prorosperms or sporozoa are very powerful stimulants to the division and multiplication of cellular structures.

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# THE LIGAMENTS OF THE CATARRHINE MONKEYS, WITH REFERENCES TO CORRESPONDING STRUCTURES IN MAN. By ARTHUR KEITH, M.B.

(From the Anatomical Department, Aberdeen University.)

NOTWITHSTANDING the very considerable amount which has been written concerning the bones, muscles, and brain, with lesser notices upon the nerves, blood-vessels, and viscera of the old world monkeys, the ligaments have been mentioned in only an incidental manner. It is not that the ligaments merit this neglect, for perhaps of all structures they are the most susceptible of adaptative influences, and even in a rudimentary condition they are most persistent. Their close study gives data towards the elucidation of the evolutionary history of species.

My descriptions are based principally upon the minute examination of the ligaments in two individuals of the group Cynomorpha (*Macacus niger* and *Cercopithecus sabaeus*). The cursory examination of many other members of the group shows that the description here given holds good for the whole group. With slight modifications, the description is applicable to the ligaments of the Anthropomorpha.

The adaptative changes in human ligaments are less marked in the fœtus: hence, for comparison, human fœtuses of the third, fourth, sixth, and ninth months were used.

The differences in the ligamentous structures in the three groups of animals—Man, Anthropomorpha, and Cynomorpha—are due to adaptations for their different postures and modes of progression.

In Man the axis of the body is perpendicular to the plane of

motion, and the weight is supported upon the feet. In the Anthropomorpha the axis of the body is perpendicular to the plane of motion, but the weight is mostly supported from the hands.[1] In the Cynomorpha the axis of the body is parallel to the plane of motion, both hands and feet assisting in support.

The disposition of the ligaments harmonises with the style of progression in each individual group.

## FASCIÆ AND LIGAMENTS OF THE INFERIOR EXTREMITY.

*Scarpa's Fascia.*[2]—The frog is placed inside its skin much as a hand is placed within a glove, only that the skin is bound to the deeper parts by definite septa or mesenteries. The inguinal septum is attached along the inguinal furrow, and binds the skin to the underlying parts along the groin. Prof. Alex. Ecker shows that it not only serves to retain the skin in position during flexion and extension of the thigh, but through it nourishment is supplied to the surrounding skin, and products of absorption returned to the body, so that it is properly a lymphatic structure. A thin mesentery-like membrane binds the skin to the underlying parts in the groin of the cat, and occurs evidently in all mammals. If elliptical incisions be made above and below the inguinal furrows in any ape, and the enclosed piece of skin be lifted up, a mesenteric structure will be found containing the superficial lymphatic glands. It is attached to the skin along the inguinal furrow, and deeply it fuses with the sheaths of the femoral vessels, the scrotal tissue, the round ligament of the female, and the underlying muscular sheaths. It evidently fulfils the same functions as the similar structure in the groin of the Frog, and cannot in any manner be properly described as a splitting of the superficial fascia of the abdomen. If the groin of a human fœtus be examined before the deposition of fat has taken place, Scarpa's

[1] Somehow, zoologists have persisted in describing the Anthropomorpha as if they were ground forms, walking on hands and feet. It would be quite as true to describe the gait of the seal upon land as its natural mode of progression. Man bears the same relationship to the *Catarrhini* as does the seal to the *Carnivora*.

[2] For an accurate account of Scarpa's fascia, see Struthers' *Anatomical and Physiological Contributions*, 1854.

fascia will be seen to answer to this description given of the Quadrumana; only in Man, owing to the close adhesion of the skin to the underlying parts and the deposition of fat, this fascia is neither so distinct nor so extensive as in other members of the Primates.

In the axilla there is a similar structure. In the Frog it is formed by the anterior division of the ventral septum (Ecker). In the Quadrumana it is much more diffuse than Scarpa's fascia. This lymphatic mesentery of the axilla is attached to the subcutaneous tissue along a line extending from the neighbourhood of the coracoid process nearly to the iliac angle of the scapula. It contains the greater part of the lymphatic glands of the axilla. A corresponding structure seems to exist in the child, although in a diffuse form, for water forcibly injected beneath the skin is arrested at a line stretching from the proximity of the coracoid towards the inferior angle of the scapula.

*Poupart's Ligament.*—Properly speaking, there is neither a "Poupart's" nor a "Gimbernat's" ligament in the Cynomorpha, and their presence in the Anthropomorpha is little more than indicated.

There is no thickening of the tendon of the obliquus externus abdominis, stretching from the anterior superior iliac spine to the pubic crest.

The combined obliquus abdominis internus and transversalis abdominis arise from the whole of the anterior border of the ilium and arch closely over the ilio-psoas muscle. Internal to the ilio-psoas muscle a fascial membrane arises from the ilio-pectineal line, runs upwards and inwards in front of the rectus abdominis, and decussates in the middle line with that of the opposite side. It lies behind and defends the external inguinal opening. Morphologically it forms part of the internal obliquus abdominis sheet, and represents the small triangular fascia in Man.

The sheath of the ilio-psoas muscle is thickened as the muscle leaves the abdomen, and this is the only representative of Poupart's ligament in the Quadrumana.

*The Inferior Annular Ligament of the Ankle* (*Ligamentum lambdoideum*).—In the Quadrumana this ligament is present in its typical mammalian form, *i.e.*, as a loop rising from the

digital extremity of the extensor surface of the os calcis, and encircling the tendon of the extensor communis digitorum. The fibres of the extensor brevis digitorum arise from it and in common with it. In Man the loop is still preserved, but its primitive simplicity is masked by its adhesion to the deep fascia of the ankle. Strengthened bands of this fascia bind it to the tibia above and the scaphoid below, constituting the ligamentum lambdoideum. That these bands are artificially separated pieces of the deep fascia explains the varying descriptions given in different text-books of human anatomy. In explanation of this modified condition in Man, one must remember that in him the mobility of this joint is less, while the stability is greater, than in any other member of the Primates. In other words, it is one of the many adaptations to his upright posture.

*The Superior Annular Ligament of the Ankle.*—In the Primates, as in the Mammalia generally, this ligament is Y-shaped. The part corresponding to the stalk of the Y arises from the posterior border of the base of the internal malleolus and crosses the inner aspect of the tibia adherent to the periosteum. At the anterior border of the tibia the stalk bifurcates into two limbs—a *superior*, which crosses the extensor tendons to become attached to the fibula, and corresponds to the superior annular ligament of human anatomy; and an *inferior* limb, which runs behind the extensor tendons and in front of the capsule of the ankle-joint, to be inserted into the extensor aspect of the os calcis immediately behind the ligamentum fundiforme, to which it may be more or less adherent. The result of this bifurcation of the superior annular ligament is that a loop is formed that prevents the tendons slipping over on to the inner surface of the tibia in the almost constantly inverted position of the foot in the Quadrumana.

In Man, all three parts—the stalk, the superior and inferior limbs—are present. The superior annular ligament in him is formed entirely by the superior limb: the inferior limb may be seen as a band of rudimentary fibres crossing behind the extensor tendons and lying on the anterior aspect of the capsule of the ankle, while the stalk has become very adherent to the periosteum, but is plainly seen in the fœtus. The modifica-

tion of this ligament in Man must also be set down to limited mobility of his ankle-joint.

*Loop Ligaments of the Peronei Muscles.*—On the lateral surface of the os calcis there are two strong ligamentous loops; one binds down the peroneus longus, while the other contains the peronei medius and brevis. On the dorsal aspect of the base of the fifth metacarpal bone is a minute loop for the peroneus medius, and when this muscle is much degenerated its tendon adheres to the loop, and appears thus to have an attachment to the fifth metacarpal bone. In Man, these peroneal loops have become adherent to the overlying fascia in a manner similar to that of the loop of the extensor communis digitorum. All these loop ligaments are probably of the same morphological nature.

*The External Lateral Ligament of the Ankle-Joint.*—It possesses an anterior, middle, and posterior limb, as in Man; only the posterior is longer and stronger, while the anterior limb is weaker.

*The Internal Lateral Ligament of the Ankle-Joint and the Inferior Calcaneo-Scaphoid Ligament.*—They do not differ materially from the same ligaments in Man, except that the human ligaments may contain some elements described in the next ligament.

*The Internal Tibio-Tarso Metatarsal Ligament of the Quadrumana.*—This is the characteristic ligament of the quadrumanal foot, and, as far as I know, has never been hitherto described, and I venture to give it the above name. Its existence is dependent upon the prehensile nature of the quadrumanal foot, and only rudiments of it are present in the human foot. It consists of three parts:—(1) sustentaculo-navicular, (2) tibio-navicular, (3) naviculo-metatarsal. The third part is frequently alluded to in observations on the anatomy of the Quadrumana.

The tibio-navicular part is a rounded cord, running from the internal malleolus to the sustentaculo-navicular part of the ligament, and with it is inserted into the navicular bone. It lies along the anterior border of the internal lateral ligament of the ankle-joint, but is easily separable from it. In the human fœtus it is evidently represented by the prominent rounded anterior border of the internal lateral ligament.

The sustentaculo-navicular part of the ligament bridges the tendon of the tibialis posticus muscle, which is here enclosed in a synovial sheath and runs along the plantar aspect of the tarsus to be inserted into the bases of metatarsi II, III, IV. In its course, the ecto-cuneiform obtrudes itself into the tendon, giving it the appearance of a flexor of the tarsus. The sustentaculo-navicular part of this ligament corresponds to that part of the anterior annular ligament of the wrist which ensheaths the flexor carpi radialis. The tibialis posticus is thus a flexor of the metatarsus, as is the flexor carpi radialis of the metacarpus, and the one is the serial homologue of the other.[1]

In Man, the tendon of the tibialis posticus muscle has become adherent to the sustentaculo-navicular ligament, and has thus acquired an apparent insertion to the scaphoid. This also is an adaptation to the upright posture.

The naviculo-metatarsal ligament bridges the concavity on the inner border of the foot formed by the ento-cuneiform. Behind, it is in part attached to the navicular bone and in part continuous with the sustentaculo-navicular ligament, and in front is inserted into the inner side of the base of the metatarsal bone of the hallux. Beneath it, in the concavity of the ento-cuneiform, is inserted the tarsal part of the tibialis anticus muscle, while the tendon of the metatarsal part of that muscle is inserted into the base of the hallucial metatarsus in common with this ligament. The extensor proprius hallucis perforates this ligament. It thus becomes, in the first place, an abductor of the hallux, and an extensor when abduction is completed. This perforation occurs in all Quadrumana.[2]

In speculations as to the morphological nature of the loop-ligament of the extensor communis digitorum, one must keep this ligament in view as well as the peroneal loops.

In Man, the naviculo-metatarsal ligament is represented by tendinous fibres adherent to the insertion of the tibialis anticus muscle, and inserted into the base of the metatarsal bone of the

[1] Professor Huxley, in his Lectures "On the Structure and Classification of the Mammalia," pointed out this homology, but in *Quain's Anatomy* (tenth ed.) vol. ii. pt. 2, it is stated to be the homologue of the radio-carpus.

[2] Th. L. W. Bischoff states (*Anatomie des Hylobates leuciscus*) that this perforation is absent in the Hylobates. I have found it invariably present.

big toe. Its existence depends on the power of abduction of the hallux, and consequently becomes rudimentary when that power is lost.

*The Dorsal Astragalo-Metatarsal Ligament of the Foot.*—This is such a prominent ligament on the dorsum of the simian foot that it can scarcely have escaped former observation, although I can find no reference to it. It runs beneath the extensor brevis digitorum, from the neck of the astragalus to the base of metatarsus III, and slightly also to the bases of metatarsi II and IV. When the foot is in a condition of prehension, this ligament strengthens the arch between the grasping toes and the astragalus, and it may be regarded as an accessory prehensile ligament. On the dorsum of the fœtal human foot it is plainly enough to be seen, although its borders are not so distinctly marked as in the quadrumanal foot. It is best seen in the fœtus at or near full time, and I may add that all the ligaments here referred to can be better seen in that stage than in any other.

*The Superior Calcaneo-Cuboid Ligament.*—This ligament is relatively stronger than in the human foot.

*The Ligamentum Fundeiforme of the Flexor Longus Hallucis.*—This is yet another of the "prehensory" group of ligaments of the quadrumanal foot, retaining the tendon of the flexor longus hallucis in position during the various degrees of abduction that occur in prehension. It is a strong ligamentous loop at the plantar base of the hallucial metatarsus, attached by one extremity to the base of metatarsus II, and by the other to the plantar tubercle of the ento-cuneiform. It is embedded in the plantar septum, which separates the abductor hallucis from the flexor brevis digitorum, and appears to be a specialised part of it. The mesial head of the flexor brevis digitorum arises partly from it.

If, in a newly-born child, the abductor hallucis be gently separated from the flexor brevis digitorum, a thin membranous-looking loop, without very distinct borders, will be found to cross the tendon of the flexor longus hallucis at the base of the metatarsal bone. This loop is, apparently, the representative of the highly developed loop in the Quadrumana.

*The Plantar Fascia.*—In the Cynomorpha, as is well known, the plantar fascia is the direct continuation of the plantaris

tendon. The tendon on the calcis lies in a synovial groove, but transverse ligamentous fibres bind it so strongly to the surrounding periosteal tissue that the plantaris muscle can exercise but little tensory power on the fascia. As the fascia leaves the heel it divides itself into an internal spreading part and an external narrow ligamentous portion which runs over the base of metatarsus V, to which, however, it firmly adheres. It then turns inwards, and joins the internal spreading portion. Its final insertion is similar to that in the human foot. If the plantar fascia be dissected off together with the skin, there will be observed on its tarsal aspect a transverse band of fibrous tissue radiating from the base of the fifth metatarsal bone towards the base of the great toe.

*The Deep Transverse Tarso-Metatarsal Ligament of the Foot.*—Upon lifting the tendon of the peroneus longus from its groove on the tarsus, this strong ligament is seen running from the bases of metatarsi III and IV inwards to the plantar tubercle of the ento-cuneiform. In Man it is relatively weak, running mostly from the base of metatarsus II to the ento-cuneiform.

*The Long Plantar Ligament.*—Its greater part arises from the plantar tubercle of the os calcis, but many of its fibres can be traced backwards almost to the insertion of the tendo-Achilles. It bridges the groove for the peroneus longus tendon, glides over an articular tubercle on the base of metatarsus V by means of a sesamoid bone, and is attached mainly to the bases of metatarsi IV and V. The musculi contrahentes arise from it, and appear like a forward continuation.

*Vincular Ligaments of the Fingers and Toes.*—There are three vincular ligaments for each digit, one binding the flexor tendons to the middle phalanx, one binding them to the basal phalanx, and the third, much weaker than the other two, binds them to the fibro-cartilaginous shield over the flexor aspect of the metatarso-phalangeal joint. These three transverse vincular ligaments are the only ones demonstrable in the human fœtus.

*Ligaments of the Knee-Joint.*—Mr J. B. Sutton[1] has produced

[1] "Ligaments, their Nature and Morphology," *Jour. Anat. and Phys.*, vols. xviii., xix., xx.; also separately, W. K. Lewis, London, 1887. I am largely indebted to Mr Bland Sutton's very suggestive work, but believe that Professor Thane rightly regards most muscles as having an independent morphological value.

evidence to show that the internal lateral ligament is, morphologically speaking, a fibrous part of the adductor magnus muscle, while the external lateral ligament may be the divorced tendon of origin of the peroneus longus muscle. I have failed to verify his statement that in the human fœtus at the third month these ligaments are in direct continuity with their "maternal" muscles, although I have examined five fœtuses ranging from the third to the fifth month. In a fœtal lemur (*Nycticebus tardigradus*) the adductor magnus had a tibial insertion, but the internal lateral ligament was quite separate from it. In a young pig the fibres of origin of the peroneus longus were distinctly traceable to the external condyle of the femur over the knee-capsule, but distinctly in front of the external lateral ligament; and I have several times made the same observation in different members of the Cynomorpha. The lateral ligaments of the knee-joint are well marked in the Frog. Some degenerated fibres of the adductor magnus and peroneus longus muscle may enter into the composition of the lateral ligaments to some extent, but the bases of the ligaments are apparently independent of muscles.

*Internal Lateral Ligament of the Knee-Joint.*—In all the Quadrumana this is a broad, strong, and well-defined ligament, attached by a characteristic rounded origin to the internal condyle of the femur, and, bridging the popliteus muscle, is fixed to the inner surface of the tibia. The tendon of the semi-membranosus, surrounded by a synovial sheath, which is continuous with the fascia over the popliteus muscle, plies freely beneath it. As Professor Langer has pointed out in the Orang,[1] the semi-membranosus acts to a considerable extent as a pronator of the leg in the Quadrumana. In Man the tendon of the semi-membranosus has contracted adhesions to its sheath, and thereby to the popliteal fascia, just as the tibialis posticus tendon has done in the foot. By this means the insertion of the semi-membranosus has been thrown backwards, so that it becomes in Man almost entirely a flexor of the knee-joint.

*The External Lateral Ligament of the Knee-Joint.*—In the Quadrumana it is a rounded cord with the usual relationship.

*Ligamentum Posticum of the Knee-Joint.*—The absence of

[1] *S. B. Ak der Wien*, lxxix. Band. iii. Abtheilung, 1879, pp. 177–223.

the band of insertion from the semi-membranosus has been already noted. The two heads of the gastrocnemius arise from a couple of sesamoids, which are embedded in the capsule of the joint and ply over the extremities of the femoral condyles. These sesamoids are connected across the intercondylar fossa by a strong band, which forms the sharp semi-lunar upper border of the ligamentum posticum. Fibres from the soleus muscle can be traced from the head of the fibula over the ligamentum posticum to this semi-lunar border, so that the degenerated condylar origin of the soleus muscle may be looked upon as one of the morphological elements entering into the composition of the ligamentum posticum. In the human fœtus there is a suggestion of this upward continuation of the soleus.

*The Anterior Part of the Knee-Capsule.*—In the Quadrumana three distinct encapsulating layers can be distinguished. These are:—

(1) A layer continuous with the fascia lata, traceable over the ligamentum patellæ, to which it intimately adheres.

(2) A layer continuous with the extensor quadriceps femoris, of which the ligamentum patellæ is a strengthened part.

(3) The proper synovial capsule.

The other ligaments of the knee-joint require no particular description.

*Ligaments of the Hip-Joint.*—Professor Bischoff[1] observed that the ligamentum teres of the hip-joint was well developed in the Gorilla. This observation has several times been verified in the Chimpanzee: Owen[2] and Langer[3] found it absent in the Orang, although traces were present. In the Gibbon it is invariably present, and after the limb was severed from the trunk by all but the ligamentum teres, I found it sustained a weight of 25 lbs. without rupturing. Morphologically, it may be part of the general capsule of the joint, which has been cut off by the confluence of the lateral wings of the caput femoris, just as a part of the ligamentum posticum of the knee-joint would be isolated were the condylar extremities of the femur to coalesce. The whole of the femoral neck is included in the

[1] Th. L. W. Bischoff, *Anatomie der Gorilla*, München, 1879.
[2] *Proc. Zool. Soc.*, London, 1830.
[3] *S. B. Ak der Wien*, Band lxxix. Abtheilung iii.

capsule; and as Owen[1] observed in the Orang, the anterior and inferior aspects of the neck are covered by synovial membrane. Cowper's band, evidently of the same nature as the ligamentum teres, from which it has been separated by the confluence of the articular surface of the caput femoris, runs along the under surface of the neck, adherent to the periosteum. A synovial mesentery binds the lower part of Cowper's band to the capsule of the joint.

*The Capsule of the Hip-Joint.*—The ilio-femoral, ischio-femoral, and pubo-femoral bands are somewhat more prominent than in Man. Owen remarks that the ischio-femoral band is strong in the Orang, and Langer makes a similar observation on the ilio-femoral band.

One of the most peculiar features of this ligament in Man is the spiral arrangement of its fibres. When the thigh of a monkey is in its natural position, *i.e.*, at less than a right angle to the axis of the lumbar vertebræ, the fibres of the capsule run in a transverse direction; it is only when the thigh is almost completely extended that a spiral arrangement of the fibres exists in the hip-capsules of the Anthropomorpha, in which the thigh is carried during progression, at an angle of about 130° to the axis of the body.

*Sacro-Sciatic Ligaments.*—The ischio-caudal muscle becomes more fibrous as the tail becomes shorter. In the Semnopitheci it is almost completely muscular; in the Macaci it is semi-fibrous; in the Anthropomorpha it becomes, with the disappearance of the tail, almost completely fibrous.

In the Cynomorpha the great sacro-sciatic ligament is represented merely by a thickened under part of the sheath of the gluteus maximus. The sheath on the under surface of the gluteus maximus muscle arises from the tips of the first three transverse processes of the tail, and is lost in the ligamentous tissue on the ischial callosity. In the shorter tailed Macaci, such as *M. arctoides*, this part of the gluteal sheath has become very strong, and gives origin to many fibres of the gluteus maximus. In the Anthropomorpha, although not so strongly developed as in Man, it is yet of considerable size, and arises from the side of the sacrum and first coccygeal vertebra, and is attached to the ischial tuberosity as in Man. Fibres of the

[1] *Proc. Zool. Soc.*, London, 1830.

gluteus maximus arise from it. At its origin it is continuous with the posterior sacro-iliac bands.

It has been suggested that the great sacro-sciatic ligament represents an ancient part of the biceps tendon of origin. In the human fœtus a number of the biceps fibres run over the ischial tuberosity, and become continuous with this ligament, but so also do fibres of the ischio-cavernosus. There may also be included in the great sacro-sciatic ligament the tendon of origin of the last caudo-tibial muscle which occurs normally in some Lemurs, and was found by Church in a member of the genus Cebus. The real basis of the ligament seems to me to be the great lateral inter-muscular septum. Its origin from the tips of the transverse processes, and its continuity through the sacro-iliac ligaments with this lateral septum in the loins, indicates such a relationship.

*Sacro-Iliac Ligaments.*—In the sacro-iliac articulation a synovial cavity is invariably present. On the pelvic aspect of the articulation there are merely transverse ligamentous fibres. The dorsal sacro-iliac ligaments arise from the pleuro-epiphysial elements of the sacrum, mostly from that of the second sacral vertebra, smaller bundles arising from the first and third, and are attached to the ilium as in Man. These posterior sacro-iliac bands are continuous below with the great sacro-sciatic ligament, and above with the ilio-lumbar ligament which belongs to the same series. It arises from the pleuro-epiphysial element of the seventh or fifth lumbar vertebra, as the case may be, and is continuous with the lateral septum in the loins from which the obliquus internus abdominis arises. It, as well as the posterior sacro-iliac ligaments, appear to be specialised parts of this septum, and not, as suggested by Mr Bland Sutton, degenerated muscles of the levator costal series, for in that case these ligaments would arise from the accessory processes of the lumbar vertebræ. All the transverse processes (pleuro-epiphyses) of the lumbar vertebræ are embedded in the lateral septum, and are bound by it to the last rib.

## Fasciæ and Ligaments of the Superior Extremity.

*The Posterior Annular Ligament of the Wrist.*—There are five synovial canals in this ligament, two of which are partly

subdivided, so that they may be said to be seven. These are for:—

(1) Abductor pollicis longus; (2) extensor carpi radialis, longior and brevior; these are separated from each other only at the carpal extremity of the canal; (3) the extensor communis digitorum, extensor indicis, and extensor proprius pollicis, which is separated from the other tendons only at the carpal extremity of the canal; (4) extensor minimi digiti; (5) extensor carpi ulnaris.

The posterior annular ligament of the wrist is composed of two elements:—(1) the deep fascia of the forearm, which is attached to the radial ridges and the pisiform bone; (2) proper carpal ligaments, which may represent at the wrist the fundiform ligaments of the ankle. These proper carpal ligaments are obscured by the close adhesion of the fascial portion of the ligament, and by the irruptive ingrowth of the radial ridge lying between the extensores carpi and the extensores digitorum tendons. Two of these proper carpal ligaments enter into the formation of the annular ligament. Both arise from the dorsal aspect of the cuneiform bone; one runs under the extensor tendons of the digits and carpus, and fuses with the sheath of the abductor pollicis; the other crosses the extensor tendons of the digits, and becomes adherent to the carpal extremity of the radius. The first occupies the position of the inferior limb of the superior annular ligament of the ankle, while the second may correspond with one limb of the extensor digitorum loop at the ankle. In the human fœtus, the fascial and carpal components of the posterior annular ligaments are so closely adherent that they cannot be separately distinguished.

On the dorsal surfaces of the carpal extremities of the radius and ulna, there is a well-marked oblique ligament which prevents over-pronation.

*The Anterior Annular Ligament of the Wrist.*—It is always extremely strong, with attachments as in the human hand, only it adheres to the base, not the apex of the pisiform bone. Part of the abductor longus pollicis is inserted into the base of the first metacarpal bone, a part is attached to the trapezium, while a third and very considerable part runs over the trapezium—where it has a small sesamoid embedded in it—and crosses the

annular ligament, of which it forms the inferior border, and becomes attached to the base of the fifth metacarpal bone and subcutaneous tissue. Through this palmar insertion, the abductor longus pollicis becomes much more an abductor of the hand than of the pollex.

*The Palmaris Fascia.*—The tendon of the palmaris longus adheres but slightly to the annular ligament of the wrist. It runs directly into the palmar fascia, which is highly developed. The principal strands of the fascia run immediately beneath the longitudinal furrows of the palm, and terminate as in Man.

Professor Langer has pointed out that in the palm of the Orang there is a very strong septum of the palmar fascia attached to the unciform process and the fifth metacarpal bone. It is not peculiar to the Orang, but seems to occur in all Quadrumana, and strengthens the suspensory function of the hand as required in "brachiation."

*Ligaments of the Pisiform Bone.*—The pisiform articulates partly on the styloid process of the ulna, partly upon the cuneiform, and its synovial cavity opens freely into the wrist-joint. The apex of the pisiform is bound by a very strong ligament to the base of metacarpus V. In young specimens, some fibres of the tendo-ulnaris are continuous with this ligament, but in old specimens the upward growth of the pisiform has separated the tendon and ligament completely, in a manner similar to the separation of the long plantar ligament from the tendo-Achilles by the os calcis.

*Ligaments on the Palmar Aspect of the Carpus.*—On the palmar aspect of the carpus of the Cynomorpha there are certain distinct ligamentous bands of which there seem to be no traces in Man. The chief of these is a strong ligamentous band running from the base of the ulnar styloid to the palmar tubercle of the scaphoid. There is another from the styloid process of the radius to the same tubercle.

The distal row of carpal bones are covered on their palmar aspect by a thick fibrous pad, from which arise the ulnar head of the flexor brevis pollicis, the adductor obliquus pollicis, the musculi contrahentes, and the deep palmar fascia.

*Radio-Ulnar Ligaments.*—The dorsal radio-ulnar ligament on the carpal extremity of the forearm has already been men-

tioned. The oblique ulno-radial ligament is exceedingly strong, and at its upper extremity is partially continuous with the orbicular ligament.

In the Hylobates there is an extremely well-marked ligamentous band, rising from the external epicondyle of the humerus and inserted into the extensor border of the ulna, beyond the upper third of that bone. It lies over the extensor muscles of the forearm, and appears to be a strengthened part of the deep fascia. Some of the extensor muscles of the forearm arise from it.

*Ligaments of the Elbow.*—The orbicular ligament of the radius is stronger than that of Man, but otherwise does not differ from it. The lateral ligaments of the elbow agree with their representatives in Man, except that the internal sends a rounded cord in front of the coronoid process of the ulna to be inserted into the neck of the radius. This rounded cord prevents extreme pronation.

*Internal Brachial Ligament of Struthers.*—Dr Struthers[1] described this ligament as a fibrous band lying *behind* the internal intermuscular septum of the arm and attached to the internal epicondyle. Did this ligament represent, as Mr Bland Sutton supposes, the third part of the coraco-brachialis of Wood, it would lie in *front* of internal intermuscular septum. I have never observed a fibrous band lying in front of the internal intermuscular septum in any of the Primates, but such a band, lying behind the internal intermuscular septum and attached to the internal epicondyle, is very common in Man, and always in every species of Quadrumana, being the fascial tendon of the latissimo-condyloideus muscle. The superior rudiment of this muscle is always present in Man, as a band of fibrous tissue joining the tendon of the latissimus dorsi muscle to the long head of the triceps.

*The Ligaments and Tendons of the Shoulder-Joint.*—The tendon of the glenoid head of the biceps is bound to the interior of the shoulder-joint capsule by a synovial mesentery. This mesentery is said to exist in the early human fœtus.

The bursa beneath the subscapularis muscle communicates freely with the shoulder-joint, as in Man.

[1] See footnote in *Anatomical and Physiological Contributions.*

The middle and inferior gleno-humeral[1] ligaments are not distinctly differentiated in my specimens, but Macalister[2] states that they are well marked in the Cynomorpha. He also remarks that the special ligaments in the capsule of the shoulder-joint of the Chimpanzee are not well differentiated. In the Gorilla he observed that the gleno-humeral ligament was very strong, and also that the inferior gleno-humeral (Humphry's ligament) was well marked.[3] Mr Bland Sutton gives a list[4] of the Quadrumana in which the gleno-humeral ligament is well marked, and another in which it is but indifferently developed. It will be noticed that, according to his list, it is strongly developed in the Cynomorpha, while it is weakly so in the Anthropomorpha. This, however, does not agree with Macalister's observation on the Gorilla, and it must be remembered that most of the Anthropomorpha that have been examined are young specimens. In the human fœtus the gleno-humeral and coraco-humeral are the only ligaments marked in the capsule of the shoulder-joint.

In the Quadrumana, with exceptions in Hylobates and some individuals of the Troglodytes, the pectoralis minor is inserted into the capsule of the shoulder-joint from the angle of the coracoid process to the tip of the greater humeral tuberosity. If the tendon be cut through and thrown outwards, there will be found beneath it, and partly separate from it, a ligament stretching from the coracoid process to the great tuberosity—the coraco-humeral ligament. In Man and other Anthropomorpha, in which the pectoralis minor is inserted into the coracoid process, the coraco-humeral ligament may contain some elements belonging to the pectoralis minor muscle, but it seems incorrect to say that this ligament is a separated part of the pectoralis minor muscle.

Besides this ligament, the coracoid process is connected to the capsule of the shoulder-joint by a web of synovial tissue.

The transverse bicipital ligament is continuous in fœtal Cynomorpha with the more superficial fibres of insertion of the subscapularis. Into this transverse bicipital ligament in the

1 Terms used as in *Quain's Anatomy* (tenth edition).

2 *Annals of Nat. Hist.*, 4th series, vii., 1871.

3 *Proc. Roy. Irish Acad.*, 1872.

4 *Ligaments, their Nature and Morphology*, Lewis, London, 1887.

Cynomorpha is inserted the minute membranous tendon of the axillary platysmus.

The spino-glenoid ligament is a profuse strand of fibrous tissue attached to the root of the acromion, and radiating outwards over the capsule of the shoulder-joint. It is apparently a part of the septum lying between the infra-spinatus and supra-spinatus muscles.

*Coraco-Acromial Ligaments.*—In most of the Cynomorpha this ligament is a weak synovial-looking membrane, lying under the deltoid muscle. In the Hylobates this ligament runs upwards to the under surface of the acromial extremity of the clavicle, then under the acromio-clavicular joint, to be attached to the acromion process. The outer extremity of the clavicle rests upon this ligament. In one specimen the coraco-acromial ligament was entirely attached to the extremity of the clavicle. In a fœtal Hylobates many fibres of insertion of the pectoralis minor ran into the coraco-acromial ligament, and I have noticed a similar continuity in a young Orang.

*Clavicular Ligaments.*—The coraco-clavicular ligament is represented by only a trapezoid portion. In the Hylobates and Gorilla the clavicle is separated from the coracoid by a synovial cavity. In a fœtal Gibbon the fibres of the supra-scapular ligament were continuous with the coraco-clavicular ligament. These ligaments seem to be derived from the same source, and separated from each other by the ingrowth of the angle of the coracoid.

*Costo-Coracoid Membrane.*—Bischoff remarks that it is extremely strongly developed in the Gorilla. This is apparently the case in all Quadrumana. It has but a slight costal attachment, but is strongly adherent to the clavicle in front of the subclavius muscle and to the coracoid process. In *Nycticebus tardigradus* it runs over the coracoid to the capsule of the shoulder-joint.

The acromio-clavicular ligament appears as if it were a fibrous continuation of the acromion. There is a synovial cavity in the midst of the ligament. In the Gibbon there is a partial inter-articular cartilage.

The costo-clavicular ligament lies so closely to the lower part of the sterno-clavicular capsule that it is not easily separated

from it. In an Orang I noticed a bursa lying between this ligament and the capsule of the sterno-clavicular joint.

*The Sterno-Clavicular Articulation.*—In the Cynomorpha the inter-articular cartilage is represented by a fibro-cartilaginous ligament, projecting into the cavity of the joint from the posterior wall of the capsule, and running from the clavicle above and behind to the lower and anterior part of the clavicular notch of the sternum. On each side of this inter-articular ligament is a small synovial cavity. These cavities communicate with each other in front of the inter-articular ligament. In the Anthropomorpha the inter-articular cartilage is complete. The synovial cavities on each side are relatively small, especially the one on the sternal side. Tyson, in his "Anatomy of a Pygmie" (Chimpanzee), described the inter-articular cartilage, and says that Riolan found a bone developed in the cartilage of the sterno-clavicular joint of a Chimpanzee.

The inter-clavicular ligament is strongly developed, but it is not connected with the summit of the sternum by a T-piece.

Along the posterior surface of the sternum in the Cynomorpha are many longitudinal fibrous bands. They begin at the insertion of the sterno-hyoid muscles, and appear to be a ligamentous continuation of these muscles.

## Ligaments of the Inferior Maxilla.

The meniscus is attached above and behind to the post-glenoid ridge and to fibres of the posterior part of the capsule, which also arise from the post-glenoid ridge. The meniscus is attached in front to the articular margin of the condyloid process with the anterior part of the capsule. The anterior part of the capsule, which is extremely thin, has some fibres of the external pterygoid inserted into it. The capsule is strengthened posteriorly by a strong accessory ligament arising from the vaginal process, and attached to the posterior aspect of the neck of the condyloid process of the jaws. Externally, also, a strong ligament arises from the root of the zygoma, runs downwards and backwards, strengthening the external part of the capsule, and is attached to the neck of the condyloid process with the posterior accessory ligament

The internal lateral ligament of the jaw has the same attachments as in Man, and resembles in size and shape the same ligament in a fifth-month human fœtus.

The stylo-maxillary ligament is strong and rounded, and becomes attached to the posterior border of the ascending ramus.

The pterygo-maxillary ligament is not well defined.

The pterygo-spinous ligament is well developed and strong.

## Vertebral Ligaments.

The characteristic differences between the vertebral ligaments of the Quadrumana and Man lie in the greater diffuseness of conformation and larger development of yellow elastic tissue in the Quadrumana.

The anterior and posterior common vertebral ligaments, as well as the occipito-vertebral ligaments, are strongly developed, but less concentrated and demarcated than in Man.

The ligamenta subflava form thick masses of yellow elastic tissue; yellow elastic tissue is also markedly present in the posterior costo-transverse ligaments of the hinder ribs in the Cynomorpha, and in the same class much yellow tissue is developed in the inter-spinous ligaments lying between the fourth dorsal and first sacral spinous process.

The ligamentum nuchæ is present as a thin fibrous layer lying between the dorsal muscles in the neck.

The cervical transverse processes are connected by ligamentous bands.

## Costo-Vertebral Ligaments.

The anterior costo-central ligament resembles that in Man. The inter-articular ligament is very strong and thick, and the synovial cavities bordering it are extremely small. I have not observed any trace of a ligamentum conjugatum. The posterior costo-transverse ligament is much less developed than in Man, and, as already noted, contains much elastic tissue in the hinder ribs. The middle costo-transverse ligament is present. The superior costo-transverse ligament, which becomes inter-costal in the lower ribs, is very weakly developed. The superior costo-

transverse ligaments belong to the same sheet as the lateral septum in the loins. The ribs, as well as the costal processes of the lumbar vertebræ, are embedded in the lateral septum. The intercostal muscles become continuous with the superior costo-transverse ligament in the same manner as the obliquus abdominis internus, and the transversalis abdominis become continuous with the lateral septum in the loins.

I take this opportunity to acknowledge my indebtedness to Professor Reid for hints as to the arrangement of my material, and also to Professor Thane for the opportunities he afforded me to work at this and other allied subjects during last winter.

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The "Struthers Medal and Prize in Anatomy" was awarded in July last to Mr Arthur Keith for this research. The specimens which were submitted for its illustration have been placed in the Anatomical Museum of the University of Aberdeen.

R. W. REID,
*Professor of Anatomy.*

THE ORIGIN AND DISTRIBUTION OF THE NERVES TO THE LOWER LIMB. By A. M. PATERSON, M.D., *Professor of Anatomy in University College, Dundee.* (PLATES IV., V.)

(*Continued from p. 95.*)

## III. DISTRIBUTION OF THE NERVES OF THE LUMBO-SACRAL PLEXUS.

### 1. *To the Lower Limb.*

*Classification of the Areas of Distribution of the Nerves.*— In order to obtain a true conception of the mode of distribution of the spinal nerves which, through the limb plexus, supply the lower extremity, it is desirable at the outset to define the pre-axial and post-axial borders and the dorsal and ventral surfaces of the limb, and, further, to classify the branches emanating from the plexus in relation to these borders and surfaces. This appears to me particularly necessary for the reason that Eisler, in my opinion, has made a somewhat arbitrary delimitation of the surfaces of the limb and the nerves supplying them by drawing the pre-axial border from the front of the pubis to the inner border of the patella, and subdividing the branches of the anterior crural nerve into dorsal and ventral sets, according as they fall on either side of this line. In my opinion, the *pre-axial border* of the limb (fig. 1, Pr.) (over which dorsal and ventral nerves may quite easily overlap) is a natural border extending up from the inner edge of the foot over the inner ankle,—*in the line of the internal saphenous vein,*—along the inner border of the tibia, the inner condyle of the femur, and the inner edge of the sartorius muscle, to the groin. The *post-axial border* (fig. 1, Po.) runs along the outer edge of the foot, over the external ankle, to the back of the head of the fibula, and thence along the outer side and back of the thigh to the lower border of the gluteus maximus, by which it is directed to the coccyx. The surfaces of the limb are included between these two borders. With regard to the skin, the *dorsal* surface includes part of the buttock, the front of the thigh and leg, and

the dorsum of the foot, between the pre-axial and post-axial borders. This surface spreads out on either side, and includes a much larger area than that comprised in the *ventral surface.* The latter includes the area of skin over the inner part of Scarpa's triangle, the inner side and back of the thigh, the back of the leg, heel, and the sole of the foot. From its innervation one may regard the first named of these cutaneous areas,—over the inner part of Scarpa's triangle,—as derived from the trunk, by the growth and extension of the limb.

*The muscles* of the dorsal and ventral surfaces of the limb correspond in general to the superficial areas, but there are certain exceptions, to which later reference will be made. The following table indicates the muscles belonging to the dorsal and ventral areas respectively:—

TABLE III.

*Muscles of the Lower Limb.*

| *Dorsal Muscles.* | *Ventral Muscles.* |
|---|---|
| Pectineus (?). | Adductors. |
| Sartorius. | Obturator externus. |
| Ilio-psoas. | Obturator internus. |
| Quadriceps extensor. | Gemelli. |
| Glutei. | Quadratus femoris. |
| Tensor fasciæ femoris. | Semi-membranosus. |
| Pyriformis. | Semi-tendinosus. |
| Biceps (short head). | Biceps (long head). |
| Tibialis anticus. | Plantaris. |
| Extensors of toes. | Popliteus. |
| Peronei. | Gastrocnemius. |
| | Soleus. |
| | Tibialis posticus. |
| | Flexors of toes. |
| | Intrinsic muscles of foot. |

The nerves in relation to the borders and surfaces of the limb may be classified as follows:—

*Pre-axial border* { Ilio-inguinal nerve. Genito-crural nerve.

| *Dorsal Surface.* | *Ventral Surface.* |
|---|---|
| External cutaneous nerve. | Obturator nerve. |
| Anterior crural nerve. | Nerves to obturator internus, gemelli, quadratus femoris. |
| Superior gluteal nerve. | Tibial nerve. |
| Inferior gluteal nerve. | Nerves to hamstring muscles. |
| Nerve to pyriformis. | Small sciatic nerve (perineal branches). |
| Nerve to biceps (short head). | |
| Peroneal nerve. | |
| Small sciatic nerve (gluteal branches). | |

*Post-axial border*—Small sciatic nerve (femoral branches).

*At the pre-axial border* of the limb, at its junction with the trunk, are the ilio-inguinal and genito-crural nerves. As mentioned above, one is inclined to regard the former nerve as pertaining essentially to the trunk, and as being drawn down, as it were, in the growth and extension of the limb. Eisler has further subdivided the branches of the genito-crural nerve into dorsal and ventral series, comparing them to the lateral and anterior branches respectively of an intercostal nerve.

*At the post-axial border* is the small sciatic nerve. As stated in a former memoir (14), I regard this nerve as including elements for the dorsal and ventral areas (buttock and perinæum), as well as branches which belong essentially to the post-axial border of the limb (femoral branches). Eisler separates these femoral branches into external (dorsal) and internal (ventral) series.

Between these limits the nerves can be readily separated, both by origin and distribution, into a *dorsal* and *ventral series* in relation to the corresponding surfaces of the limb. One cannot accept Eisler's proposal to separate the branches of the anterior crural nerve into dorsal and ventral series, particularly as the chief reason which he assigns for so doing is an arbitrary delimitation of the pre-axial border and dorsal surface of the limb.[1]

*a. Distribution of the Nerves to the Skin.*—The changes which have taken place in the development of the limb, and the complexity of the arrangement of the cutaneous branches from the plexus, make the precise distribution of the spinal nerve-roots to the skin a somewhat difficult matter to determine. Herringham, from a study of the upper limb, has formulated the following rules for the distribution of cutaneous nerves:—

[1] Further, one cannot altogether agree with Eisler's attempt to homologise the nerves derived from the lumbo-sacral plexus, not merely with the lateral and anterior branches of the intercostal nerves, but also with the secondary subdivisions of the lateral branch. While approving of his homologies in general, and without criticising this further attempt in detail, one would merely observe that an intercostal nerve may have no divided lateral branch; that the subdivisions of the lateral branch are subsidiary and secondary; and that in many animals the lateral branch extends for the most part forwards (ventrally) in the body-wall, and gives off no branches of importance backwards (dorsally). It appears to be forcing the comparison with an intercostal nerve rather far to attempt to follow out to such an extent as Eisler does the homologies of the nerves derived from the lumbo-sacral plexus.

A. *Of two spots in the skin, that which is nearer the pre-axial border tends to be supplied by the higher nerve.*

B. *Of two spots in the pre-axial area, the lower tends to be supplied by the lower nerve; and of two spots in the post-axial area, the lower tends to be supplied by the higher nerve.*

There is no doubt that the truth of these rules is fully illustrated in the case of the lower limb. The cutaneous nerves are in the path of their distribution clearly related for the most part to the pre-axial and post-axial borders of the limb, only a few of them appearing directly on the surfaces; at the same time, when traced up to their spinal origin, they give a striking picture of the continuity of the distribution of the several spinal nerves involved in the plexus (figs. 1 and 2). The study of their arrangement is much simplified by figuring on the dorsal and ventral surfaces, the hypothetical dorsal and ventral axial lines, suggested by Sherrington (8, *b*)—lines which on the human limb may be traced as follows:—A dorsal axial line (figs. 1 and 2, AB) extending from the middle line over the buttock, down the outer side of the thigh to the head of the fibula, along the junction of the areas supplied by the external cutaneous and small sciatic nerves; and a ventral axial line (fig. 1, CD) on the inner side of the thigh, from the root of the penis to the back of the inner condyle of the femur, and demarcating the areas innervated by the small sciatic and obturator nerves. Sherrington regards these hypothetical lines as axes along which the several spinal nerves radiate in their distribution to the skin. Thus in front of them (pre-axially) one finds pre-axial nerves; behind them (post-axially) one finds post-axial nerves; while at the peripheral ends of the axes the intermediate nerves emanate for the supply of the more peripheral parts of the limb. Sherrington also points out that each spinal nerve, while possessing a distinct area of its own, overlaps and is overlapped by contiguous nerves, proximally, distally, and across the dorsal or ventral axial line of the limb. To such an extent does this overlapping extend, that he believes that no spot on the skin is supplied by less than two (or possibly three) spinal nerve-roots. A consideration of the mode of development of

the limb, and the growth of the limb plexus, throws some light upon the constitution of these axial lines. They may be looked upon, I think, as the remains of areas on the dorsal and ventral surfaces of the limb bud, which are innervated, not by the segmental spinal nerves which form the plexus, and which beneath these areas lie deeply, and matted together in the plexus, but in the absence of these nerves, which have not yet reached the surface, from the nearest available source.

Thus on the dorsal surface (buttock and thigh) is an area or line (figs. 5 and 6, DA) representing the meeting-place or overlapping of four widely-separated series of nerves (fig. 6): an area innervated by (1) branches from the posterior primary divisions of the first three lumbar nerves; (2) the posterior primary divisions of the sacral and coccygeal nerves (the two series being separated by a hiatus, as the 4th and 5th lumbar nerves, do not, as Sherrington points out, become cutaneous); (3) an area supplied by the most distal nerves in the lumbo-sacral plexus (small sciatic, S.1.2.3); and (4) an area supplied by the most proximal nerves of the plexus (external cutaneous, L.1.2.3). Similarly on the ventral surface (fig. 7), near the root of the limb, is an area or line (VA) representing the meeting-place of the most proximal and distal nerves of the plexus: (1) the ilio-inguinal (L.1); (2) the obturator (L.2.3.4); and (3) the small sciatic (S.1.2.3). In short, these lines of Sherrington indicate very plainly the meeting-place of widely-separated series of nerves on the surfaces of the limb, and point to the fact that in passing to supply the skin, the intermediate spinal nerves do not reach the surface of the limb near its attachment, and that nerves from other sources are requisitioned for the supply of these parts.

The innervation of the skin of the buttock presents the simplest arrangement, being supplied for the most part segmentally from the pre-axial to the post-axial border by consecutive spinal nerves from the 12th thoracic to the end of the spinal series. These nerves are lateral and posterior primary divisions of spinal nerves, and for this reason I regard the area supplied by them as derived from the trunk and drawn over the root of the limb in its growth, in the same way as the cutaneous nerve-supply of the scalp is derived from the upper cervical nerves.

The rest of the cutaneous surface of the limb is supplied by

branches which appear for the most part at the borders, and ramify over the surfaces of the limb.

Along the *pre-axial border* are the following nerves in order from above downwards, with their spinal origin (figs. 1 and 2):—

| | Origin. |
|---|---|
| *α. Dorsal Branches.* | |
| Genito-crural (crural branch) | L.1.2 |
| External cutaneous | L.1.2.3 |
| Middle cutaneous | L.2.3 |
| Internal cutaneous | L.2.3 |
| Internal saphenous (patellar branch) | L.3.4 |
| Internal saphenous (below knee) | L.3.4 |
| *β. Ventral Branches.* | |
| Ilio-inguinal | L.1 |
| Genito-crural (genital branch) | L.1.2 |
| Obturator | L.2.3.4 |

At the *post-axial border* the following branches appear from above downwards:—

| | | Origin. |
|---|---|---|
| *α. Dorsal Branches.* | | |
| Small sciatic | Buttock<br>Thigh (outer side) | S.1.2.3 |
| Peroneal | Cutaneous branches including Communicans fibularis | L.5.S.1.2 |
| *β. Ventral Branches.* | | |
| Small sciatic | Thigh (inner side)<br>Perinæum | S.1.2.3 |
| External saphenous | | S.1.2 |

Two series of nerves, lastly, appear upon the surfaces of the limb near the periphery:—

| | Origin. |
|---|---|
| *α. Dorsal Surface.* | |
| Musculo-cutaneous | L.4.5.S.1 |
| Anterior tibial | L.4.5.S.1 |
| *β. Ventral Surface.* | |
| Internal plantar | L.4.5.S.1 |
| External plantar | S.1.2 |
| Posterior tibial (calcanear branch) | S.1.2 |

Collating these results for the innervation of the respective surfaces of the lower limb, we see (1) that at the root of the limb, in both surfaces, there are gaps in the segmental distribution of the spinal nerves, only the more proximal and distal nerves appearing in the surface; and (2) that approaching the periphery, the laterally-placed nerves drop out, and those in the centre become superficial, and supply the skin in a

continuous numerical series from the pre-axial to the post-axial border.

This is seen from the following table :—

### TABLE IV.

*Distribution of the Cutaneous Nerves to the Lower Limb.*

A. *Dorsal Surface.*

| | |
|---|---|
| 1. Buttock and thigh. | |
| Skin over Scarpa's triangle | L.1.2 |
| Front of thigh | L.1.2.3 |
| Buttock and outer side of thigh | S.1.2.3 |
| 2. Leg. | |
| Front of knee | L.3.4 |
| Inner side of leg | L.3.4 |
| Outer side | L.5.S.1.2 |
| 3. Dorsum of foot. | |
| Inner side | L.3.4 |
| Dorsum | L.4.5.S.1 |
| Outer side | S.1.2 |

B. *Ventral Surface.*

| | |
|---|---|
| 1. Thigh. | |
| Inner side | L.2.3.4 |
| Back of | S.1.2.3 |
| 2. Leg. | |
| Outer side | L.5.S.1.2 |
| Back of | S.1.2.3 |
| Heel | S.1.2 |
| 3. Foot. | |
| Inner side | L.3.4 |
| Inner side of great toe | L.4.5 |
| Interval between 1st and 2nd toes | L.4.5.S.1 |
| ,, ,, 2nd and 3rd toes | L.5.S.1 |
| ,, ,, 3rd and 4th toes | L.5.S.1 |
| ,, ,, 4th and 5th toes | S.1.2 |
| Outer side of foot and 5th toe | S.1.2 |

The skin of the dorsal surface of the limb is innervated, near the attachment of the limb, by the more proximal and distal nerves of the plexus; over the front of the thigh and buttock by the first three lumbar nerves and the first three sacral nerves respectively; the front of the leg and dorsum of the foot, on the other hand, are supplied by spinal nerves forming a continuous series; the inner side of the front of the leg being innervated by L.3 and 4, the outer side by L.5.S.1.2. Similarly, the nerves of the dorsum of the foot form, as shown in the table, a continuous series from the 3rd and 4th lumbar in the inner side to the 1st and 2nd sacral on the outer side (fig. 2).

In the same way the skin of the ventral surface of the thigh is innervated by proximal and distal nerves (L.2.3.4 and S.1.2.3);

the back of the leg is supplied by L.5.S.1.2.3, and the sole of the foot and toes (fig. 9) are innervated by a continuous series of nerves just as on the dorsum of the foot (Table IV.).

It was possible to differentiate the collateral digital branches of the sole of the foot with greater ease than those distributed on the dorsum.

The conclusions derived from an examination of these results, as far as the distribution of nerves to the skin is concerned, thus closely harmonise with the rules laid down by Herringham.

In arriving at these conclusions, I have been greatly assisted by discussion with Dr Sherrington, and by a perusal of his memoir, to be published shortly, on the distribution of the sensory roots of the spinal nerves to the lower limb, and particularly by his luminous suggestion of a dorsal and ventral axial line, demarcating near the root of the limb the distribution of the more proximal and distal spinal nerves of the plexus.

The results of my dissections, lastly, will be seen to be markedly different from those formulated by Gowers (15).

*b. Distribution of the Nerves to Muscles.*—Herringham has formulated the following rules for the innervation of the muscles of the upper limb:—

A. *Of two muscles, or parts of a muscle, that which is nearer the head end of the body tends to be supplied by the higher nerve; that which is nearer the tail end by the lower nerve.*

B. *Of two muscles, that which is nearer the long axis of the body tends to be supplied by the higher, that which is nearer the periphery by the lower nerve.*

C. *Of two muscles, that which is nearer the surface tends to be supplied by the higher, that which is farther away from it by the lower nerve.*

These rules have already been adversely criticised by both Eisler and Sherrington; and my own investigations, as will be seen below, indicate so many important exceptions to them as to render them, in my opinion, inapplicable to the innervation of the lower limb. The muscles of the lower limb have undergone profound alterations in the process of development,—by the rotation of the limb, the assumption of the erect attitude, and the change in the form, attachments, and relative importance of

individual muscles, that without the aid of embryology and comparative anatomy it is a difficult matter to locate the muscles and the nerves which supply them in their proper category. The following table (V.) shows the muscles of the limb divided into a dorsal and a ventral series, along with their nerve-supply:—

TABLE V.

*Innervation of Muscles of Lower Limb.*

| Dorsal Muscles. | Nerve-Supply. | Ventral Muscles. | Nerve-Supply. |
|---|---|---|---|
| *Thigh and Buttock—* | | *Thigh and Buttock—* | |
| Pectineus<br>Sartorius<br>Iliacus | L.2.3 | Obturator internus and superior gemellus | S.1.2.3 |
| (Psoas) | L.2.3.4 | Quadratus femoris and inferior gemellus | L.4.5.S.1 |
| Quadriceps extensor | L.3.4 | | |
| Tensor fasciæ femoris<br>Gluteus minimus<br>Gluteus medius | L.4.5.S.1 | Adductor longus | L.2.3 |
| Gluteus maximus<br>Biceps (short head) | L.5.S.1.2 | Gracilis<br>Adductor brevis | L.2.3.4 |
| (Pyriformis) | S.1.2 | Obturator externus<br>Adductor magnus (1) | L.3.4 |
| | | Adductor magnus (2) | L.4.5 |
| *Leg and Foot—* | | Semi-membranosus | L.4.5.S.1 |
| Tibialis anticus<br>Extensors of toes<br>Peronei | L.4.5.S.1 | Semi-tendinosus | L.5.S.1.2 |
| | | Biceps (long head) | S.1.2.3 |
| | | *Leg—* | |
| | | Plantaris<br>Popliteus | L.4.5.S.1 |
| | | Flexor longus digitorum<br>Tibialis posticus | L.5.S.1 |
| | | Flexor longus hallucis<br>Soleus (1) | L.5.S.1.2 |
| | | Soleus (2)<br>Gastrocnemius (each head) | S.1.2 |
| | | *Foot—* | |
| | | Flexor brevis digitorum<br>Abductor hallucis<br>Flexor brevis hallucis<br>Lumbricales (1 and 2) | L.5.S.1 |
| | | Abductor minimi digiti<br>Flexor accessorius<br>Lumbricales (3 and 4)<br>Flexor brevis minimi digiti<br>Adductores hallucis<br>Interossei | S.1.2 |

In one respect the innervation of the muscles of the limb agrees with that of the skin. The muscles nearest the pre-axial border of the limb are supplied by the most proximal, those nearest the post-axial border by the most distal nerves, while the intermediate nerves alone extend to the peripheral muscles. There is an important difference, however, in this respect, that the muscles at the root of the limb on both dorsal and ventral surfaces are supplied continuously from all the nerves of the plexus.

*Dorsal Muscles.*—The muscles of the front of the thigh and buttock appear to belong to one and the same morphological series, and are named in their order in Table V. Their nerves show a regular continuity in relation to the roots of the plexus when traced up to their spinal origin. The pectineus muscle is the most pre-axial, the gluteus maximus and short head of the biceps the most post-axial muscles. The pectineus is included in the dorsal series on account of its morphology and innervation (13); although, at the same time, it must be remembered that it may contain fibres associated with the adductor muscles, and belonging to the ventral series. It seems to represent the meeting-place of the dorsal and ventral strata of muscles at the pre-axial border of the limb. The psoas and pyriformis muscles are hypo-skeletal muscles, whose connection with the limb proper is possibly not essential. The reasons for including the short head of the biceps muscle among the dorsal muscles are twofold: (1) on account of its innervation, and (2) on account of its morphological relation to the gluteus maximus muscle. The innervation of the short head of the biceps is quite distinct and separate from that of the long head of the muscle. I have shown (16) that the short head is innervated by a special branch of the external popliteal nerve, which, when traced up to the lumbo-sacral plexus, is found to be associated with the roots of the inferior gluteal nerve, and which, when examined more closely, is seen to have a similar spinal origin (L.5.S.1.2). The morphology of the muscle also shows it to be intimately associated with the gluteus maximus. In Man their only connection is at their femoral attachment, where the fascia lata encloses (and forms) the insertion of the gluteus maximus, and envelops the femoral origin of the biceps. The examination of

the two muscles in other animals, however, gives the solution of the problem. In *Ruminants* (17) the mass corresponding to the short head of the biceps is associated with the gluteus maximus in the formation of a single large muscle (*the long vastus*), while there exists at the same time a separate muscle corresponding to the long head of the biceps. In discussing the homologies of the long vastus, Chauveau describes it as homologous, in its anterior portion, with the gluteus maximus, in its posterior portion with the femoral part of the biceps muscle. In short, the junction of the long and short heads of the biceps muscle in Man indicates the union of dorsal and ventral strata at the post-axial border of the limb, just as in certain cases the existence of two strata in the pectineus muscle indicates a similar union at the pre-axial border. Between the limits of the pectineus in front, and the gluteus maximus and biceps (short head) behind, the muscles of the thigh and buttock are supplied by a continuous series of nerves (see Table V.). The muscles on the front of the leg (including the peronei), and dorsum of the foot, are supplied by the intermediate nerves of the plexus (L.4.5.S.1).

Examining Herringham's rule, given above, in relation to these muscles and their innervation, it is obvious that Rules B and C, at any rate, are inadequate. Eisler has already pointed out that the gluteus maximus, more superficial than the gluteus medius, is yet supplied by more distal nerves. I have noted four cases, further, in which the nerves to the gluteus minimus and tensor fasciæ femoris muscles were separated from the nerve to the gluteus medius, with the following result:—

| | No. X. | No. XXIII. | No. VII. | No. VIII. |
|---|---|---|---|---|
| Gluteus medius . . . | 4.5.1 | 4.5.1.2 | 5.1.2 | 5.1.2 |
| Gluteus minimus . . } Tensor fasciæ femoris . . } | 4.5 | 4.5.1 | 5.1 | 5.1 |

The deeper muscle, the gluteus minimus, is supplied by nerves more pre-axial than the muscle lying superficial to it. Again, comparing the innervation of the gluteus maximus and peronei muscles, it is seen that muscles farther away from the

long axis of the body are supplied by nerves (L.4.5.S.1) more pre-axial than are muscles nearer to it (L.5.S.1.2). The obturator internus, gemelli and quadratus femoris muscles are consigned to the ventral series for reasons given below.

*Ventral Muscles.*—This series includes the adductor and hamstring muscles of the thigh, the muscles of the back of the leg and sole of the foot. Along with them are included the obturator internus gemelli, and quadratus femoris. Of the muscles belonging to the thigh, the most pre-axial is the adductor longus; the most post-axial, the long head of the biceps. As indicated in Table V., the adductors and hamstring muscles form a continuous series, and are supplied by a continuous series of nerves, correlated to one another in their spinal origin, and proceeding to supply the muscles in consecutive order from the pre-axial to the post-axial border of the thigh.

The nerves to the hamstring muscles, as Eisler has pointed out, can be readily separated up to the plexus, where they arise on its ventral aspect, *and in close relation to the nerves for the obturator internus, gemelli, and quadratus femoris.* The latter muscles have only an incidental relation to the buttock, and are associated morphologically with the ventral muscles of the limb. Eisler dwells at length upon the origins of the nerves to these muscles, and shows that they vary correlatively with the position of the *n. furcalis* and the form of the plexus. In this my cases agree with his. He rightly places these nerves in the same category with the obturator nerve, showing that the obturator nerve (L.2.3.4) is coterminous with the origin of the nerves to these muscles (L.4.5.S.1 and S.1.2.3), and that both are ventral. There is little doubt but that, in the alteration of the position of the limb, by a process of rotation backwards of the hip-bone, the position of the obturator internus, gemelli, and quadratus femoris muscles has been profoundly changed. If in imagination one rotates back the limb, and brings the ischium—a ventral portion of the pelvic girdle—into its primitive position, these muscles will become ventral, and the quadratus femoris will take up a position pre-axial to that of the obturator internus; while the whole mass of muscles on the ventral aspect of the thigh will occupy somewhat the following position from the pre-axial to the post-axial border:—

Adductor longus.
Gracilis: adductor brevis.
Obturator externus.
Adductor magnus.
*Quadratus femoris and inferior gemellus:* semi-membranosus.
Semi-tendinosus.
*Obturator internus and superior gemellus:* biceps (long head).

The rotation of the limb explains the apparently anomalous innervation of the obturator internus by nerves placed distally to those supplying the quadratus femoris. It is notable that the only muscles of the lower limb supplied by the 3rd sacral nerve are the biceps (long head) and the obturator internus.

It will be noted (Table V.) that the adductor magnus muscle, innervated from two sources (obturator L.3.4, n. to hamstrings L.4.5), receives its nerve-supply from spinal nerves in direct continuity with one another.

My results regarding the innervation of the muscles of the leg show a vital discrepancy with Herringham's rule. Deep muscles, *e.g.*, plantaris and popliteus, are supplied by pre-axial nerves (L.4.5.S.1) and superficial ones, *e.g.*, gastrocnemius, by post-axial nerves (S.1.2). Again, I have noted (in agreement with Sherrington's observation) that the inner head of the gastrocnemius, a pre-axial muscle, is more often supplied by a distal nerve (S.3) than the outer or post-axial head (see Table of Details). On the other hand, among the deep muscles of the leg, the flexor longus digitorum and tibialis posticus are supplied by pre-axial nerves (L.5.S.1), while the flexor longus hallucis, which morphologically is a post-axial muscle, is innervated more post-axially (L.5.S.1.2). I have not always succeeded in tracing up to the plexus the small branches supplied to the muscles of the foot by the internal plantar nerve. They are all grouped together as coming from L.5 and S.1. The chief nerves to the muscles of the foot are associated with the external plantar nerve, and are derived from S.1 and 2.

The dorsal and ventral series of muscles are not supplied equally by the constituent spinal nerves of the plexus. The dorsal muscles are supplied in general by nerves more pre-axially placed; in other words, their spinal origin extends a less distance in a caudal direction than in the case of the ventral muscles. The dorsal series of muscles is supplied by the 2nd lumbar to the 2nd sacral nerve; but the only muscles supplied

by the latter are the pyriformis, gluteus maximus, and short head of the biceps; while the 1st sacral nerve is the most post-axial of those reaching the muscles of the dorsum of the foot. The ventral series of muscles is supplied by the 2nd lumbar to the 3rd sacral nerve. The 3rd sacral nerve supplies only the obturator internus and long head of the biceps, while the 2nd has an important distribution among the muscles of the calf of the leg and the sole of the foot. It may be inferred from this that a wider area of the spinal cord is implicated in the supply of the ventral series of muscles than of the dorsal series.

These results of investigations into the innervation of the muscles of the lower limb, agree generally with the less detailed conclusions arrived at by experiment by Ferrier and Yeo (18), and from clinical observations by Gowers (15). The most remarkable correspondence, moreover, is found between them, and the results arrived at by Sherrington (8, *a*) regarding the nerve-supply of similar muscles in *Macacus rhesus*, which he has localised by experiment. In Rhesus there are, as a rule, seven lumbar vertebræ, and the 5th lumbar nerve appears to be usually the *n. furcalis.* As in my cases, so here, the nerve-supply for the dorsal muscles is derived from nerves less post-axial than those of the ventral muscles. The close agreement between the results formulated above and Sherrington's conclusions is well seen when the two series are tabulated together (Table VI.).

This table shows a remarkable agreement between results arrived at by very different means. The differences which occur may well be accounted for by the differences in the methods adopted. Sherrington, for example, does not mention a special nerve-supply for the biceps (short head), nor a double innervation for the soleus. He also gives the double innervation of the adductor magnus as L.4.5 and L.7; whereas in Man the two nerves seem to be directly continuous with one another, and derived from L.3.4 (obturator), and L.4.5 (n. to hamstrings). The two investigations, however, show a marked agreement in general, indicating the same order of innervation of the muscles of the lower limb, in Rhesus and in Man, and the same continuity of the dorsal and ventral series of muscles in relation to the borders of the limb and the nerves supplying them.

One's opinion is strengthened by these results, that in the for-

## TABLE VI.

*Comparison of Innervation of Muscles of Lower Limb in Rhesus and Man.*

| Dorsal Muscles. | Rhesus. | Man. | Ventral Muscles. | Rhesus. | Man. |
|---|---|---|---|---|---|
| Psoas | L.1.2.3.4 | L.2.3.4 | Quadratus femoris and | | |
| Iliacus | 3.4 | 2.3 | gemelli | L.6.7 | L.4.5.S.1 |
| Pectineus | 3.4 | 2.3 | Obturator internus | 7.8 | S.1.2.3. |
| Sartorius | 3.4 | 2.3 | Adductor longus | 3.4 | L.2.3 |
| Vastus internus | 3.4.5 | | Gracilis | 4.5 | 2.3.4 |
| Rectus | 3.4.5 | 3.4 | Adductor brevis | 4 | 2.3.4 |
| Crureus | 4.5 | | Obturator externus | 3.4 | 3.4 |
| Vastus externus | 4.5 | | Adductor magnus (1) | 4.5 | 3.4 |
| Tensor fasciæ femoris | 5 | 4.5.S.1 | Adductor magnus (2) | 7 | 4.5 |
| Gluteus minimus | 6.7 | 4.5.S.1 | Semi-membranosus | 5.6.7.8 | 4.5.S.1 |
| Gluteus medius | 6.7 | | Semi-tendinosus | 6.7.8 | 5.S.1.2 |
| Gluteus maximus | 7.8 | 5.S.1.2 | Biceps (long head) | 6.7.8 | S.1.2.3 |
| Biceps (short head) | ... | 5.S.1.5 | Plantaris | 6.7 | L.4.5.S.1 |
| Pyriformis | 5.6.7.8 | S.1.2 | Popliteus | 6.7 | L.4.5.S.1 |
| Tibialis anticus | 5.6.7 | L.4.5.S.1 | Flexor longus digitorum | 5.6.7 | 5.S.1 |
| Extensor long. digitorum | 5.6.7 | 4.5.S.1 | Tibialis posticus | 5.6.7 | 5.S.1 |
| Extensor hallucis | 5.6.7 | 4.5.S.1 | Flexor longus hallucis | 5.6.7 | 5.S.1.2 |
| Peronei | 5.6.7 | 4.5.S.1 | Soleus (1) | 6.7.8 | 5.S.1.2 |
| Extensor brev. digitorum | 6.7 | 4.5.S.1 | Soleus (2) | | S.1.2 |
| | | | Gastrocnemius | 6.7.8 | S.1.2 |
| | | | Flexor brevis digitorum | 6.7.8 | 5.S.1 |
| | | | Abductor hallucis | 5.7.8 | 5.S.1 |
| | | | Flexor brevis hallucis | 7.8 | 5.S.1 |
| | | | Lumbricales (1 and 2) | 7.8 | 5.S.1 |
| | | | „ (3 and 4) | | S.1.2 |
| | | | Adductor hallucis | 6.7.8 | S.1.2 |
| | | | Abductor min. digiti | 6.7.8 | S.1.2 |
| | | | Flexor accessorius | 7.8 | S.1.2 |
| | | | Interossei | 7.8 | S.1.2 |
| | | | Flex. brev. min. dig. | 7.7 | S.1 2 |

mation of the musculature of the limb, a given muscle is derived from the union of parts of adjacent segments entering into the formation of the limb, and that the nerves corresponding to such segments subdivide so as to contribute corresponding segmental elements to the muscle. In that way one can account for the remarkable uniformity of the innervation of the muscles of the lower limb in Man and Rhesus; and for the fact that, according to Sherrington's observations and my own, each muscle of the limb appears to be supplied from at least two spinal nerves.

*c. Innervation of the Knee-joint.*—The knee-joint was the only one whose nerve-supply was particularly attended to, owing to the ease with which the nerves could be traced to it.

The branches from various sources were noted in a considerable number of cases (see Table of Details), with the following results:—

| Nerves. | Normal Cases. | Abnormal Cases. |
|---|---|---|
| Anterior crural (n. to vastus internus) . Obturator (n. to adductor magnus) . | L.3.4 | L.3.4.5 |
| Internal popliteal . . . . . External popliteal . . . . . Recurrent tibial . . . . . | L.4.5.S.1 | L.5.S.1 |

In both normal and abnormal examples the joint is innervated by L.3.4.5.S.1. In normal cases the 4th lumbar nerve has the greatest share in supplying the joint, and after it the 5th; in abnormal cases the chief supply is from the 5th lumbar, and next to it from the 1st sacral nerve.

## 2. *To the Perinœum.*

The separation of the pudic nerve into its component parts, and the analysis of the spinal origin of its several branches have given in my hands results which, to a great extent, confirm those of Eisler. While, however, he considers the origin of the pudic nerve to be dependent upon the position of the *n. furcalis*, and to be correlated to that of other nerves of the lumbo-sacral plexus, my cases indicate the origin of the nerve to be the same, whether the *n. furcalis* is L.4 or L.5 (see Table of Details). Moreover, Eisler derives the nerve from the first four sacral nerves, or (in exceptional cases) from the last lumbar and first three sacral nerves. I have not succeeded in any of my cases in discovering a root of the nerve from any spinal nerve anterior to the 2nd sacral.

Eisler points out that in its origin the inferior hæmorrhoidal branch is always more post-axial than the remainder of the nerve, and arises from S.3.4, S.2.3.4, or S.2.3, in different cases, and that, in its course, it is frequently separate and more or less independent. In both these points my dissections give confirmatory results.

I further made the attempt to separate perinæal from penile branches up to their origin, with results which do not appear in

the table, but which were very evident in dissection (fig. 8). When the pudic nerve arose from S.2.3.4, the inferior hæmorrhoidal branch took away the constituent fibres from S.4, and some from S.3($c$); the perinæal branch comprised the greater part of S.3, and a minor portion of S.2($b$); and the penile branch comprised a minor part of S.3, and a major portion of S.2($a$). The perinæal branches of the small sciatic nerve arise also from S.2.3, as a rule. The cutaneous innervation of the perinæum is illustrated diagrammatically in fig. 8. It is generally agreed that the perinæal organs are axial and ventral, that the penis is most pre-axial, the parts around the anus the most post-axial. One would further point out that these organs belong to a region which is really post-axial to the position of the limb. These points are clearly illustrated by the innervation of the parts; the penis, scrotum, and anus ($a$, $b$, $c$, fig. 8) receive respectively more and more post-axial nerves as one proceeds caudally; and these nerves (S.2.3.4) are coterminous with those which form the caudal limit of the lumbo-sacral plexus proper. The most interesting point in this connection arises in relation with the innervation of the penis. The dorsum of the penis at its root is supplied by the 1st lumbar nerve (ilio-inguinal, L.1), the most pre-axial nerve entering into the composition of the lumbo-sacral plexus; the rest of the penis is supplied by the 2nd and 3rd sacral nerves, the most post-axial nerves entering into the composition of the plexus. Here, then, is the meeting-place in the ventral axis of the body of the ventral terminations of the nerves which bound the lumbo-sacral plexus in front and behind. This region is the meeting-place of two widely-separated series of nerves; between which the intermediate nerves are drawn out in their entirety to form the limb plexus. Here may be said to be the axial commencement of Sherrington's "ventral axial line of the limb" to be traced into continuity with a similar line on the limb itself, which on the ventral surface demarcates the area of distribution of the ilio-inguinal, obturator, and small sciatic nerves. A similar line may be drawn in relation to the upper limb, on the front of the chest, corresponding to the junction of the nerves limiting in front and behind the brachial plexus (3rd and 4th cervical nerves from above, 2nd thoracic below). This statement

agrees with observations made by Ross (2), Sherrington (8), and myself (14).

## *Conclusions.*

The main results of this investigation may be summarised here.

There is a well-marked *individual variability,* as other observations have previously shown, in the composition of the lumbo-sacral plexus. The position of the plexus shows a tendency to shift in relation to the spinal cord, and this shifting is much more frequent in a caudal than a cephalic direction. This fact forms an adverse argument to Rosenberg's theory of the phylogenetic shortening of the vertebral column.

The variations in the position of the limb-plexus, as shown by Eisler's observations, are not, strictly speaking, segmental—that is, do not imply a shifting of a whole spinal nerve, but may affect only a few (contiguous) fibres of a nerve; and the limits within which the variations occur are very narrow—between the 12th thoracic, or more frequently the 1st lumbar nerve and the 3rd sacral nerve. These two facts indicate (1) a variability in the extent of the area of spinal cord involved in the composition of the plexus—in the restriction or amplification of the area of outflow of the spinal nerves from the cord to the limb; and (2) that the segmental character of the spinal nerve-roots possesses mainly a morphological significance, and from the point of view of the composition of the plexus and the innervation of the limb is not of primary importance.

The examination of the spinal origin of the several nerves derived from the lumbo-sacral plexus confirms in the main the results of Eisler. The origin of the different nerves varies with the position of the *n. furcalis* for the most part, and with the position of the plexus formation generally; but the several nerves of distribution to muscles and skin preserve a similar and constant relation to one another, irrespective of changes in the position of the plexus.

The *associated variability* of the constitution of the plexus, and the origins of the nerves derived from it, implies the existence of a still deeper variability in the position of the columns or tracts of cells in the spinal cord which preside over the innervation of the limb.

Among the cases examined only one showed a correlated variation of the vertebral column and lumbo-sacral plexus. That case supports the view that the osseous and nervous variations may be related to one another. More information, however, is wanted before one can decide whether or not they are only coincident.

The spinal nerves entering the lumbo-sacral plexus are distributed in numerical order, and in a continuous series to the dorsal and ventral surfaces of the lower limb from the pre-axial to the post-axial border. The central spinal nerves in the plexus extend farthest into the limb, the proximal and distal nerves a less distance, as one passes from a proximal to a distal point in the pre-axial border, and from a distal to a proximal point in the post-axial border. The number of nerves supplying the pre-axial border of the limb is greater than that supplying the post-axial border; in other words, the distal nerves extend farther into the limb than the proximal nerves of the plexus—*e.g.*, the penultimate nerve (S.2) extends peripherally to the skin of the outer border of the foot and the intrinsic muscles of the sole, while the 3rd lumbar supplies no muscles and only a small cutaneous area below the knee.

In regard to the *innervation of the skin*, at the root of the limb in relation to the pre-axial and post-axial borders, there is a less distinct division of the cutaneous nerves into dorsal and ventral branches than elsewhere—*e.g.*, ilio-inguinal, genito-crural, small sciatic. On the dorsal and ventral surfaces at the root of the limb there are areas or lines (Sherrington's *dorsal and ventral axial lines*) indicating the meeting-place (and overlapping) of the most proximal and distal nerves of the plexus. In front of them, pre-axially, the skin is supplied by more proximal nerves; behind them, post-axially, by more distal nerves; while at the peripheral end of the area or line the intermediate nerves appear, and take their proper place in the innervation of the skin. These lines appear to indicate the vestiges of areas which, in the absence of the nerves proper to them (these in their course to the periphery of the limb being buried deeply in its substance), are supplied from the nearest available source. The intermediate nerves are carried out to the periphery of the limb in their entirety, and cannot reach the surface so readily as the more proximal and distal nerves.

The results of my investigations regarding the innervation of the skin fully testify to the adequacy of the rules laid down by Herringham for the cutaneous innervation of the upper limb. Subject to the qualification introduced by the adoption of these hypothetical axial lines of Sherrington, there is distinct evidence of the continuity of the nerve-supply of the limb from the root to the periphery on the pre-axial and post-axial borders.

In connection with *the innervation of the muscles of the limb*, the rules formulated by Herringham for the supply of the muscles of the upper limb do not appear applicable to those of the lower limb. In their innervation the muscles follow the same general law as the skin. They are supplied by a continuous series of spinal nerves from the pre-axial to the post-axial border on both surfaces of the limb. The centrally-placed nerves extend to the periphery, the proximal and distal nerves extending a shorter distance into the limb. The muscles of the thigh and buttock are supplied by all the constituent nerves of the plexus in order from before backwards, the muscles of the leg and foot only by intermediate nerves; *e.g.*, on the dorsal surface, the thigh and buttock are supplied by the 2nd lumbar to the 2nd sacral nerve; the muscles of the leg and foot by the 4th and 5th lumbar and 1st sacral nerve; on the ventral surface, the muscles of the thigh are supplied by the 2nd lumbar to the 3rd sacral; the muscles of the leg by the 4th lumbar to the 2nd sacral; the muscles of the foot by the 5th lumbar to the 2nd sacral.

A smaller number of nerves are implicated in the innervation of the muscles of the dorsal than the ventral surface of the limb. The dorsal muscles are supplied by the 2nd lumbar to the 2nd sacral (the last-named nerve only supplying three muscles (*gluteus maximus, pyriformis, biceps* (*short head*)). The ventral muscles are supplied by the 2nd lumbar to the 3rd sacral nerve (the last-named nerve again only contributing slightly to the innervation of the limb, and supplying two muscles (*obturator internus* and *biceps* (*long head*)). One infers from this that a more extensive tract of the spinal cord is involved in the supply of the larger ventral stratum than the smaller dorsal stratum of muscles.

The results of these investigations into the innervation of the

muscles of the limb in Man agree very closely with those obtained by Sherrington regarding the innervation of the muscles of *Macacus rhesus*. The two cases are examples of a lumbo-sacral plexus occupying different levels in connection with the spinal cord, but otherwise the spinal origin ascribed to the various muscular nerves is almost identical in both cases. Our results point almost conclusively to the fact that each muscle of the limb is supplied by more than one spinal nerve. This fact lends support to the opinion that, in the development of the musculature of the limb, each muscle is formed by the union of parts of adjacent segments entering into the composition of the limb-bud, and that the nerves belonging to such segments, subdivide so as to contribute to the muscle when formed its corresponding segmental elements.

At the pre-axial and post-axial borders of the limb, near the root, there is a fusion of the dorsal and ventral strata of muscles, as indicated by their morphology and innervation. At the pre-axial border the *pectineus* muscle (which may be represented by two strata, each supplied from a different source), at the post-axial border the *biceps* (of which the short head belongs to the dorsal stratum, the long head to the ventral stratum of muscles) represents the fusion of the two series of muscles.

*The knee-joint* is innervated by the 3rd, 4th, and 5th lumbar, and 1st sacral nerves. Of these the nerves contributing to the greatest extent to the supply of the joint in normal cases are the 4th and, to a less extent, the 5th lumbar nerve; in abnormal cases (*i.e.*, when the plexus occupies a more post-axial position), the chief nerves are the 5th lumbar, and, next to it, the 1st sacral nerve.

*The perinæum* derives its nerve-supply partly from the most proximal nerve of the lumbo-sacral plexus (1st lumbar), mainly from the most distal nerves (2nd, 3rd, and 4th sacral). An analysis of the branches of the pudic nerve shows that the spinal nerves composing it are distributed in numerical order from before backwards; the 2nd and a minor part of the 3rd sacral nerves supply the penis; the 3rd and a minor part of the 2nd form the perineal branch; the 4th and a minor part of the 3rd, the inferior hæmorrhoidal branch. The innervation of these parts indicates that they are placed morphologically in

the ventral axis of the body, and in a position post-axial to that of the hind limb, the nerves supplying them being continuous with those which innervate the post-axial border of the limb.

The root and part of the dorsum of the penis are supplied by the ilio-inguinal nerve (1st lumbar), the rest of the organ by the 2nd and, to a less extent, the 3rd sacral nerves. These are respectively the most pre-axial and post-axial nerves entering into the formation of the lumbo-sacral plexus proper; the root of the penis is thus the meeting-place in the ventral axis of the trunk of the ventral terminations of the nerves which bound the plexus before and behind. Thus this region, the point of junction of two widely-separated series of nerves, between which the intermediate nerves are drawn out in their entirety to form the limb plexus, may be regarded as the axial point of commencement of Sherrington's "ventral axial line of the limb." This point may be traced into continuity with a similar line on the limb itself, which in the ventral surface demarcates the area of distribution of the ilio-inguinal (1st lumbar), obturator (2nd, 3rd, and 4th lumbar),—and small sciatic nerves (1st, 2nd, and 3rd sacral).

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## EXPLANATION OF PLATES IV., V.

Figs. 1 and 2. The innervation of the skin of the lower limb. In these figures the limb is twisted on its axis so as to represent in each the ventral (fig. 1) and dorsal surface (fig. 2). Fig. 1 shows how the dorsal areas encroach on the ventral surface, whose pre-axial (Pr.) and post-axial borders (Po.) are represented by rows of small circles. The lines AB and CD represent the hypothetical dorsal and ventral axial lines of the limb, and the meeting-place of the more proximal and

distal roots of the plexus. The letters and numbers in both figures refer to the names of the cutaneous nerves and their spinal origin as follows :—T.1.2, distribution of iliac branch of last thoracic ; L.1, L.2, L.3, post. prim. div. of first three lumbar nerves ; P.S.P., posterior sacral plexus ; S.C.P., sacro-coccygeal plexus ; I.I., ilio-inguinal (L.1) ; G.C., genito-crural (L.1.2) ; I.C., internal cutaneous (L.2,3) ; M.C., middle cutaneous (L.2.3) ; E.C., external cutaneous (L.1.2.3) ; Obt., obturator (L.2.3,4) ; Pat., patellar branch of internal saphenous (L.3.4) ; I.S., internal saphenous (L.3.4) ; M.C., musculo-cutaneous (L.4.5.S.1) ; A.T., anterior tibial (L.4.5.S.1) ; S.Sc., small sciatic (S.1.2.3) ; C.F., cutaneous branches of peroneal nerve, including communicans fibularis (L.5.S.1.2) ; E.S., external saphenous (S.1.2) ; C., calcanean branch of posterior tibial (S.1.2) ; E.P., external plantar (S.1.2) ; I.P., internal plantar (L.4.5.S.1).

Figs. 3 and 4. The innervation of the muscles of the lower limb. The letters refer to the names of the muscles, the figures to the spinal nerves supplying them. Fig. 3 (ventral muscles)—O.I., obturator internus ; Q.F., quadratus femoris ; A.L., adductor longus ; Gr., gracilis ; A.B., adductor brevis ; O.E., obturator externus ; A.M., adductor magnus ; S.M., semi-membranosus ; St., semi-tendinosus ; Bi., biceps (long head) ; Po., popliteus ; Pl., plantaris ; Ga., gastrocnemius ; So., soleus ; F.D., flexor longus digitorum ; T.P., tibialis posticus ; F.H., flexor longus hallucis ; I.P., muscles innervated by the internal plantar nerve ; E.P., muscles innervated by the external plantar nerve. Fig. 4 (dorsal muscles)—S.G., gluteus medius, minimus, and tensor fasciæ femoris ; Py., pyriformis ; I.G., gluteus maximus ; Pe., pectineus ; Sa., sartorius ; Q.E., quadriceps extensor ; Bi.², biceps (short head) ; Ext., tibialis anticus, extensor longus digitorum, extensor proprius hallucis ; Per., peronei ; E.B., extensor brevis digitorum.

Fig. 5. Diagrammatic section through half the trunk and hind limb of a mammalian embryo, to show the relation of the limb nerves to the surfaces of the limb-bud—D.A. and V.A., dorsal and ventral areas (explained in text).

Fig. 6. Semi-diagrammatic representation of the dorsal surface of the hind limb of a mammalian embryo, showing the relation of the limb nerves to the dorsal surface at the root of the limb. D.A. = dorsal area ; 1–8 = posterior primary divisions of the lumbar and first three sacral nerves ; 4 and 5 represent the 4th and 5th lumbar nerves not giving off cutaneous branches ; 1′–8′ = the anterior primary divisions of the same nerves, in their distribution to the skin of the lower limb ; 4′ and 5′ (4th and 5th lumbar) do not send branches to the dorsal area ; the dotted line, $\alpha$–$\beta$, represents the boundary of distribution to skin of the posterior and anterior primary divisions of the spinal nerves.

Fig. 7. A semi-diagrammatic representation of the ventral aspect of the hind limb, showing the relation of the limb nerves to the ventral surface at the root of the limb ; V.A. = ventral area (explained in text) ; 1′–8′, the anterior primary divisions of the 1st lumbar to the 3rd sacral nerve ; 5′ (5th lumbar) does not send a branch to the ventral area.

Fig. 8. Scheme of the innervation of the perinæum—*a* - penis; *b* = scrotum; *c* = ischio-rectal fossa; *d* = coccyx; X = root of lower limb; L.1 = distribution of 1st lumbar (ilio-inguinal); S 3.2 = penile branch of pudic; S.3.2 = perinæal branch; S.4.3 = inferior hæmorrhoidal; S.3.2′ = perinæal branch of small sciatic nerve; V.A.L. = ventral axial line (explained in text).

Fig. 9. The innervation of the skin of the sole of the foot—E.S. = external saphenous nerve; I.S. = internal saphenous; C. = calcanean branch of posterior tibial; I.P. = internal plantar nerve; E.P. = external plantar nerve. The numerals refer to the spinal origins of the several nerves; those in relation to the toes to the origin of the digital nerves.

# VARIATIONS IN THE POSITION AND DEVELOPMENT OF THE KIDNEYS. By MACDONALD BROWN, F.R.C.S., Lecturer on Anatomy at Surgeons' Hall, Edinburgh. (PLATE VI.)

**(Read before the Anatomical Section of the British Medical Association, Newcastle, August, 1893.)**

FOR some years back I have paid special attention to the position, relative size, and relations of the kidney, and have been also fortunate in coming across some rare forms of abnormality.

In this paper I purpose to fully describe those forms of renal abnormality which I have examined, and at the same time to suggest a method of classification which will embrace all deviations from the normal.

Only a few years ago these deviations could have been interesting to the anatomist or pathologist alone; but now that clinical methods have become more exact, and the domain of the surgery of the kidney fairly established, I believe that a short account of the more striking cases may not be without interest to the profession.

The bibliography of the subject is enormous in its extent; and therefore, for the sake of brevity, I have contented myself with merely referring to those cases which seem to bear specially on my own observations.

I have classified the abnormal conditions met with under seven headings:—

I. Kidneys normal in position and size, but altered in form.
II. Kidneys normal in position, but altered in relative size.
III. Variations in number.
IV. Variations in position,—*i.e.*, displacements.
V. Malformations.
VI. Variations of the ureters.
VII. Vascular abnormalities.

## I. Kidneys normal in Position and Size, but altered in Form.

Among those which I examined, very slight changes in shape were not uncommon; *e.g.*, kidneys somewhat longer or broader than usual—sometimes approaching the more globular fœtal condition—in a few, discoid in form. Anything like distinct lobulation was extremely rare, although traces of the original condition in the shape of irregular indistinct fissures were occasionally made out.

I have examined the kidneys carefully in 117 subjects, and in seven of these the lobulation was fairly marked. While in all of these seven cases it was well marked on the anterior surface, in only two did it appear on the posterior. The persistence of this fœtal characteristic has been frequently noticed, and only recently Andrew [1] exhibited some well-marked specimens.

## II. Kidneys normal in Position, but altered in relative Size.

Although the left kidney is usually rather longer and narrower than the right, the relative weights are generally stated to be practically equal.

I was surprised to find in many instances a considerable difference in relative size and weight. While in the great majority of cases the difference was fractional, in 18 cases it was pronounced, and in 7 extreme. In the body of a man aged 37, the right organ was found symmetrically lessened in all its diameters, and weighed 2 ounces. The microscope showed the renal tissue to be quite normal. The left kidney weighed 6½ ounces, and was considerably larger in all diameters. Instances are recorded of much greater differences than this, but in most of the cases the smaller kidney had undergone fibrous transformation, while the corresponding organ had become hypertrophied. Thus Watson [2] describes a case where the left kidney weighed 9½ ounces, while the right only

[1] Andrew, "Specimens of Lobulated Human Kidneys," *Glas. Med. Journ.*, vol. xxxviii. pp. 427–429.

[2] Morison Watson, *Ed. Med. Jour.*, July 1874.

measured $1\frac{1}{2}$ by 1 inch, and consisted mainly of fibrous tissue. containing scattered tubules and glomeruli. The ureter was pervious at the bladder, but became a fibrous cord before reaching the neighbourhood of the small kidney.

I am inclined to believe that this relative difference in the size of healthy kidneys is more common than is generally supposed.

## III. Variations in Number.

Absence of both kidneys must be exceedingly rare. Cases are mentioned by Rayer[1] in fœtuses and full-termed children, also occasionally in monsters. Coen[2] mentions a case of a fœtus in which none existed. Life under such circumstances must be impossible after a very few days.

Polk[3] removed the only kidney a patient had, and death ensued after 11 days of complete anuria. Moulin[4] of Trieste relates an impossible case of a girl of 14 years of age, at whose post-mortem neither kidneys, ureters, nor bladder were found. She urinated through the umbilicus, which was near the pubis. He endeavoured to account for the condition by surmising that the urinary products were probably excreted by the liver, and carried to the umbilicus by the umbilical vein.

Very rarely indeed is the number of kidneys more than two. Still, one or two instances have been cited by Rayer and others,[5] where a supernumerary gland existed, placed either near the other two kidneys, or elsewhere in the abdomen or pelvis. Rayer states that in these additional kidneys, each possessed a distinct ureter.

*Single Kidney.*—I was fortunate to find a good example of this remarkable condition. (*Vide* Plate VI.) The subject was a man of 48 years of age, in whom the left kidney alone was present.[6]

A very careful dissection of the condition was made, and afterwards the parts were removed.

The kidney measured 6 inches in length, $3\frac{1}{4}$ inches at the

[1] Rayer, *Traité des Maladies des Reins*, vol. iii.
[2] Coen, *Ann. Univ. di Med. e Chir. Milano*, 1884, cclxvii. 52–82.
[3] Polk, *New York Med. Jour.*, 1883, vol. xxxvii. p. 171.
[4] *Moulin*, quoted by Morris.
[5] *Rep. Superv. Surg. Mar. Hosp.*, Washington, 1884–5, pp. 148–50.
[6] W. Turner, *Edin. Med. Jour.*, February, 1865, describes and figures a case of absence of left kidney.

broadest part across, and nearly 1¼ inches in thickness. It weighed as nearly as possible 7 ounces. It was of normal shape. Its position and relations were normal, except that it extended down nearly to the iliac crest, and lay more external to the vertebral column than usual. The tunica adiposa was well defined.

The order of the structures entering the hilum was slightly altered, the artery lying in front of the vein. The adrenal body was normal in size and position—the capsule was healthy, and stripped off easily—and the microscope showed that the renal tissue was perfectly healthy.

The renal arteries were two in number, and both were given off by the aorta. The renal vein was normal in every respect, and had opening into it, as usual, the left spermatic and capsular veins. The vessel corresponding to the right renal artery passed outwards behind the vena cava, and after giving off the right adrenal, passed downwards and outwards, and ended in three branches, two to the head of the pancreas and one to the duodenum.

There was no trace whatever of the right kidney. In the position of the adrenal body four little separate masses were found, connected together by a network of fibres. The microscope showed that each mass was adrenal in structure, and the connecting fibres were doubtless sympathetic in nature. The middle capsular artery sent branches to all four masses.

On examining the pelvic organs I found a fairly large right ureter in normal position, and on tracing this upwards found that it ended in a small fusiform knob near the pelvic brim. It was 5 inches in length, but was only pervious from the bladder for two inches; the succeeding two inches was absolutely solid; the remaining inch composed the fusiform dilatation, and was filled with a mucoid opalescent fluid.

Cases of "Single Kidney" are exceedingly rare. In nearly 12,000 autopsies made in the various London hospitals, only three cases were discovered. Indeed, only slightly over 100 cases have been recorded altogether, and even many of these were doubtfully true "Single Kidney."

Morgagni in 1769 divided cases of Single Kidney into two classes—

1. Those due to a coalescence of two organs.

2. Cases where only one kidney exists.

Morris[1] classifies Single Kidney into three groups—

1. Unsymmetrical,—*i.e.*, entire absence of one kidney.

2. Solitary,—*i.e.*, fusion of both organs into one mass; *e.g.*, horseshoe and other forms.

3. Atrophic forms—where one kidney is so little developed, or so completely destroyed, that there is practically only one organ present.

I do not consider either classification satisfactory. Single Kidney is "Single Kidney," and not a fusion of two. No doubt in Morris's third class there is physiologically only one kidney present, but still the rudiment of the other exists; and do we not, moreover, frequently come across examples of one kidney having become practically useless by disease, and the other, usually hypertrophied, doing the work of both?

I would therefore describe as "Single Kidney" only those cases in which one organ is congenitally and entirely absent.

The second group of Morris I have classed under malformations; while atrophic cases, when not distinctly pathological, are placed in class 2.

Having therefore attempted to define clearly what I understand by "Single Kidney," let me now discuss some points regarding it, as brought out by my own case, as well as by the cases of others.

1. *Size.*—The kidney is usually considerably enlarged, although by no means invariably so.

In Gubbin's[2] case it weighed 13 oz., while in Morison Watson's it was normal in size, and somewhat fœtal in character. In Mackey's[3] case it was double the normal weight; in my own it weighed almost 7 oz.

It therefore by no means follows that because one kidney is absent, that the other must of necessity be double the normal size, or even very much enlarged. So much of the literature is hazy and indefinite on this point, that one is almost forced to believe that in many of the recorded instances when the single

[1] *Surgical Diseases of the Kidneys*, 1885.

[2] Gubbin, *British Med. Journal*, Jan. 20, 1883, p. 115.

[3] Mackey, *British Med. Journal*, Sept. 17, 1887, p. 626.

organ was very large, the renal tissue must have undergone considerable pathological change.

Nephrectomy is as yet in its infancy, and we do not possess sufficient knowledge of autopsies on successful cases to know to what extent compensatory hypertrophy has taken place, but I much doubt if that will be found to be very extensive.

In short, it appears that one kidney of normal size is capable of performing those renal functions necessary for life, if not for health.

2. *Form.*—Alterations in form are not very common. In some cases more circular, in others more elongated, and even angular or sigmoid, it is in many relatively thicker. I have found that in the great majority of recorded cases the organ was, as in my own, perfectly normal in shape, although, of course, increased in all its diameters.

3. *Position.*—It is rare to find a single kidney occupying an unusual position, although it has been found in the iliac fossa or pelvis. Mackey found the organ higher and nearer the mesial plane than usual. In my case the vessels were abnormally long, and the kidney lay considerably more external than normal. It extended downwards almost to the iliac crest; otherwise its relations called for no special attention.

4. *Side.*—The left kidney is more commonly absent than the right.

5. *Bladder and Ureters.*—According to Roberts,[1] the ureter and renal vessels were always absent in what he calls congenital cases.

Many cases are published where no trace of a ureter corresponding to the missing kidney was found, and the mucous membrane of the bladder over the usual site of its mouth smooth and intact.[2] In others a rudimentary ureter was present, connected with the bladder below, and varying in length and patency.

In five instances of true unsymmetrical kidney recorded in the Transactions of the Pathological Society of London, in only one was the rudimentary ureter present. In Rayer's list, in 12 out of the 17 cases the ureter was absent. In many, as in Liebmann's

[1] Roberts, *Urinary and Renal Diseases*, 1885.

[2] Murchison, *Path. Soc. Trans., Lond.*, vol. x. p. 190.

case, it was quite rudimentary; in Sudduth's[1] it measured 2½ inches, and was hollow right up to its extremity; in my own it was 5 inches long.

I cannot agree with Northrup[2] that its bulbous end represents a rudimentary kidney.

It is a very strong presumption in favour of a solitary kidney being a true single one when its ureter is single.[3]

Some authors mention a deflection of the bladder to the renal side. I did not notice this in my own case.

6. *Vessels.*—The arteries supplying a single kidney are, as might be expected, larger than usual, and nearly always more than one is present. They are usually derived from the aorta, supplementary ones being supplied by the iliacs.

In most of the recorded cases the renal vessels on the affected side were absent; in my case they passed to adrenal, pancreas, and duodenum.

7. *Adrenal bodies.* — The adrenal body on the side upon which the kidney is present is usually normal in size and position. The position of the opposite one seems to vary somewhat. Beumer[4] states that out of 48 cases of solitary kidney which he had collected, it was only absent in 5. Roberts asserts that it is usually awanting in congenital cases. Actual cases are recorded by Mackey and others where it was undoubtedly absent.

Liebmann[5] mentions a case of Single Kidney lying largely in the pelvis, which had two adrenals associated with it. In my own case it occupied the usual position, although broken up into four discrete masses.

I am inclined to believe that the second adrenal body is practically always present, and that it lies nearly always in its normal position, although it may be somewhat altered in form.

It is very rare to find the relations of structures at the hilum altered: you will see from the drawing that in this Single Kidney, the artery and vein have changed places.

[1] Sudduth, *Med. Reg. Phil.*, Feb. 1889.
[2] Northrup, *Med. Rec. Chic.*, June 22, 1890.
[3] *Merkel*, quoted by Morris.
[4] Virchow's *Archiv.*, vol. lxxii. p. 344.
[5] Liebmann, *Cent für Chir.*, 1887.

8. *Congenital defects in other organs.*—These appear to be exceedingly common.

Beumer found that in 13 cases of women with Single Kidney, 8 had defective conditions of the uterus, vagina, &c., on the affected side. He even goes the length of saying that congenital defects and anomalies of the sexual organs ought to suggest the probability of congenital alterations of the kidneys. Leech [1] found in his case that there was double uterus and vagina: in Greenfield's [2] the testis, vas deferens, and seminal vesicle of the affected side were all absent. Similar conditions are also recorded by Gatti,[3] Coen,[4] Guttmann,[5] Ogston,[6] Bartscher,[7] and many others. That such congenital defects should so often occur with congenital alterations of the kidneys is not to be wondered at, considering the close embryonic relationship which the kidneys bear to the other derivatives from the Wolffian body and ducts, and urogenital sinus.

In my own case there was no genital defect or abnormality.

9. *Sex.*—It is unquestionably much more common in males: according to Roberts' statistics, something like four to one.

10. *Cause of Single Kidney.*—The absence or small size of the artery at whose termination a viscus is developing, or is about to form, must play an enormously important rôle in the maldevelopment of that viscus. This is well attested by the vascular conditions in the recorded cases of Single Kidney.

Single Kidney does not seem of itself to influence the duration of life. Cases are recorded at all ages, from fœtal life upwards. Only last year Lenniere [8] records a case at 64 years of age.

It is interesting to note that Single Kidney is not unknown among the lower animals. Sutton states that it occurs in the horse, sheep, hen, &c., and is then twice the normal size. One of my own students has found it in the pigeon.

[1] *Leech*, quoted by Roberts.

[2] Greenfield, *Path. Soc. Trans. Lond.*, vol. xxviii. p. 164.

[3] Gatti, *Gazz. d. osp. Milano*, 1881, ii. 927.

[4] Coen, *Riv. Clin. di Bologna*, 1883, 3 s., iii. 708–719.

[5] Guttmann, *Archiv. f. Path. Anat. Berlin*, 1883, vol. 92, pp. 187–191.

[6] Ogston, *Obst. Soc. Lond.*, 1880, vol. 21, p. 57.

[7] Bartscher, *Ein Seltener Fall von beideiseitigem Merindefest neben anderen Missbildungen*, Kiel, 1890.

[8] Lenniere, *Jour. d. Sc. Med. de Lille*, 1892, i. 614–617.

## IV. Variations in Position.

I believe that displacements of the kidney are much more common (at any rate in lesser degree) than is generally supposed.

This class includes not merely cases where one or both organs occupy altered positions, but also those cases of Movable Kidney regarding whose features, causation, symptomatology, and treatment so much has been said and written.

Ebstein[1] and Roberts[2] classify these displacements into fixed and movable, while Newman[3] and others subdivide the movable forms into Movable and Floating.

It seems to me exceedingly difficult to separate cases of fixed dislocation from those in which the mobility is very slight. It is well known that in children the kidneys possess considerable range of movement, and in the adult there is always a small degree of mobility. The vast host of papers which have been published on the subject only serve to increase this difficulty, as in many cases of so called Movable Kidney the mobility was so trifling that other observers would have undoubtedly classified them as fixed dislocations. Then, again, great confusion has arisen because many authors decline to recognise any difference between the terms "movable" and "floating," other than that of mere degree—*i.e.*, a floating kidney being a very movable one.

The literature of the subject is increasing daily, and one has only to look over the list of published papers extending over the last ten years, to realise how beneficial it would be, could a uniform definition of these three terms—fixed, movable, and floating—be agreed upon by common consensus.

I have scarcely come across a dozen recorded cases in which the movement was practically nil, and I would therefore propose to enlarge the meaning of the term "*fixed,*" and suggest that misplaced kidneys be classified as follows:—

1. *Fixed displacements,* where the mobility is always less than 1 inch in any direction.

2. *Movable Kidney*—where the mobility exceeds the last

[1] Ebstein, *Ziemmsen's Cyc. Med.*, vol. 15, p. 761.

[2] Roberts, *Urinary and Renal Diseases.*

[3] Newman, *Glas. Med. Journ.*, vol. 20, 1883, 81–139. Also *Clinical Lectures on Kidney Diseases,* Glas., 1888.

figure—where the organ is mobile in its relaxed adipose capsule, or between the muscular wall of the abdomen and the peritoneum.

3. *Floating Kidney*, where the kidney has a mesonephron, and floats in the peritoneal cavity.

Let me first say that slight displacements are very common. Newman found in 1000 post-mortems that in 24 cases one or both kidneys were abnormally placed. I found slight displacements of one or both organs in 11 of my cases. Dislocation or dystopia is, however, usually confined to one kidney, and most commonly the left.

Roberts divides these displacements into congenital and acquired, and states that the former variety are usually altered in form and size, and often associated with some alteration of the large gut and peritoneum.

It is always, of course, indicative of the congenital nature of the condition, when the renal vessels are not lengthened and stretched, but quite abnormal, derived from arteries near the organ in its new site.

The displacement may be upwards as in Waldeyer's[1] case, where the left kidney lay higher than the spleen and pressed the diaphragm upwards. The organ may be placed nearer the mesial plane of the body, or further away from it. The common direction is however, downwards, and especially in acquired forms, where it is practically constant, due to pressure of enlarged organs, tumours, &c.

Potain[2] describes a curious displacement by anteversion. Usually the dislocated organ has its long axis vertical or extremely oblique—although Carslaw[3] describes a case in which it was almost transverse.

The kidney may lie partly or wholly in the iliac fossa, as in cases described by Mahon,[4] Laudé,[5] Hepburn,[6] &c.: over the sacro-iliac joint, as in Morgan's[7] case: near the aortic bifurca-

[1] Waldeyer, *Ziemmsen's Cyc. of Med.*, vol. 15, p. 761.
[2] Potain, *Gaz. des hopit.*, Aug. 21, 1891.
[3] Carslaw, *Glasgow Medical Journal*, vol. xxxi. p. 381.
[4] Mahon, *Jour. of Anat. and Phys.*, vol. xxiii. p. 339.
[5] Laudé, *Bull. d. l. Soc. Anatomique*, April 16, 1891.
[6] Hepburn, *Journ. Anat. and Phys.*, vol. xxv. p. 24.
[7] Morgan, *Med. Rec. Chi.*, July 7, 1889.

tion, as in Canton's[1]: just at or within the pelvic brim, as in Howden's,[2] and in many other examples. It may be fixed beside the uterus, lie between the rectum and bladder, and may give rise to various troubles, *e.g.* by touching the ovary, painful menstruation, as in Polk's case, &c.

In cases mentioned by Rayer[3] and Hohl[4] a misplaced left kidney caused an obstacle to parturition. A dislocated kidney may simulate aneurism, and has been known to cause obstruction to the bile ducts.[5]

My own case (*vide* Plate VI.) resembled generally those of Poirier and Canton. It, however, presented some features which I have not found described in any of the published papers on the subject.

It occurred in a woman of 46 years of age.

The organ nestled into the bifurcation of the aorta, and lay upon the body of the 5th lumbar vertebra and the first two sacral bodies, and overlaid the left common iliac vessels. Its axis was nearly vertical, its shape practically normal, except that its lower end was somewhat broader than its upper. The organ was slightly mobile, but its movement did not exceed that found in my first class. It was entirely covered anteriorly by peritoneum, and had a considerable fibrous attachment to the vertebræ and also to the sheath of the left iliac vessels.

The curious point about the case was, that the kidney seemed to have undergone a considerable amount of rotation around a vertical axis, whereby its posterior surface became practically anterior—the hilum being turned to the right side and placed somewhat posteriorly. The ureter was normal, although very short.

After making a careful sketch of the condition, I removed the organ. Its anterior (in reality posterior) surface showed fairly distinct lobulation, thus bearing out Merkel's statement that when the kidney is pelvic in position it tends to remain more or less lobulated throughout life. The arterial supply was afforded

[1] *Canton*, quoted by Roberts.
[2] Howden, *Journ. Anat. and Phys.*, vol. xxi. p. 551.
[3] Rayer, *Malad. d. Reins*, vol. iii. p. 769.
[4] *Hohl*, quoted by Newman.
[5] Legg, *Path. Soc. Trans. Lond.*, vol. xxvii. pp. 467–475.

by two trunks, both given off by the right internal iliac artery. The vein was single, and opened into the left internal iliac vein.

The organ was absolutely healthy, but differed mainly from other described cases, such as Howden's,[1] Canton's,[2] &c., in the position of the hilum and the altered direction of the surfaces.

The genital organs in these cases of dislocation are often more or less abnormal, especially on the affected side, but in my case they were perfectly normal.

The adrenal occupied its usual position in the abdomen; and the fact that in cases of single and dislocated kidney it usually does so, shows clearly that its development is quite distinct from that of the kidney, as also that its normal relation to it is an accidental one.

Movable kidney has formed a theme of interest for over three centuries, observations upon it having been published by Riolan[3] in 1562 and by Mesué[4] in 1581.

I have already alluded to the unfortunate confusion which has arisen on account of the looseness with which the terms "movable" and "floating" have been used by different authors. It must not be supposed for a moment that a true floating kidney is simply one in which the mobility is greater than that found in a movable one; as a matter of fact, it is often considerably less.

Movable kidney has no mesonephron and is generally acquired, says Morris. The latter point I am inclined to deny, inasmuch as in very many cases the condition of the vessels undoubtedly proves its congenital nature. Still, acquired cases are common.

The right kidney is usually the one affected. It is more common in women, and in them at usually from 25 to 40 years of age.

As to the percentage of its occurrence, Lindner[5] states that out of every 5 or 6 women, one has a floating kidney, while Rollet[6] maintains that the proportion of movable kidney is

[1] Howden, *Journ. Anat. and Phys.*, vol. xxi. pp. 551–557.
[2] Canton, *Trans. Path. Soc. Lond.*, vol. xiii. p. 148, 1862.
[3] Riolan, *Manuel. d'Anat. et. Path. Lyons*, 1562.
[4] Mesué, *Opera Omnia Venetiis*, 1581.
[5] Lindner, *Ueber die Wanderniere der Frauen*, Berlin, 1888.
[6] Rollett, *Pathologie und Therapie der beweglicher Niere*, 1866.

about 1 in 250. I cannot believe the percentage is anything like so high. Landau[1] says that movable kidney is often overlooked on account of its settling into normal position in the cadaver.

An immense amount has been written upon the causation of movable kidney. It has been attributed to a sudden blow, fall, or jump—tight-lacing—hernia—sudden emaciation—displaced uterus—old localised inflammations—trauma, &c. &c.

It has been recently suggested that in women the weight of the dress hung from a constricted waist, and the wearing of high-heeled shoes increase the lumbar curve, and therefore throwing the kidneys forwards, tend also to the production of movable kidney. Be this as it may, the fact that movable kidney occurs mainly during the child-bearing time in women proves clearly that the laxity of the abdominal walls and peritoneum is, after all, the most important factor. The greater frequency of the right organ being affected is attempted to be explained in many ways. Newman attributes it to the influence of the liver; Lancereaux[2] to the sympathetic connection between right ovary and right kidney being very close, and so menstruation acting regularly as a congester and loosener of the kidney.

Landau[3] lays stress on the differences in the attachments of the two glands—the right not being so firmly bound to the abdominal wall as the left, &c.

Floating Kidney is a very rare condition, and is clearly defined by Newman.[4] It always possesses a mesonephron, formed by a congenital disposition of the peritoneum, and necessarily associated with an elongation of the renal vessels. It can only move to the extent of its mesentery. The layers of peritoneum are not necessarily quite close together, but if the peritoneal investment move with the kidney, it is "floating."

He quotes cases observed by Henderson,[5] Priestley,[6] and Steven.[7] Many other authors have observed similar cases.

[1] Landau, *Die Wanderniere der Frauen*, Berlin, 1881.
[2] *Lancereaux*, quoted by Newman.
[3] *Landau*, as before.
[4] *Newman*, as before.
[5] Henderson, *Med. Times and Gazette*, vol. ii. 501, 1859.
[6] Priestley, *ibid.*, 1857, p. 262.
[7] Steven, *Glas. Med. Journ.*, Oct. 1883.

## V. Malformations.

The two kidneys, apart from mere differences in size and shape, sometimes become more or less fused together, constituting the "solitary" forms of many authors.

Under this group are found horseshoe kidneys. These occur 1 in 1600 cases, and are the commonest of the malformations. Other fusions are said only to be present 1 in 10,000 cases.[1]

All degrees of fusion have been found, from the horseshoe to the most complete incorporation. The malformed double organ may lie in or near the mesial plane of the body—in the lower lumbar and iliac regions—or even in the pelvis.

Its shape varies much. It may be sigmoid, as in Brösicke's[2] case, or quite irregular and unshapely. Kruse and others record instances of complete fusion. One feature is common to all these forms, viz., the possession of two ureters.

Even in normal kidneys the ureters are subject very often to irregularity.

The hilum may be absent, and the ureter pass out from the lower aspect of the organ.

## VI. Variations of the Ureters.

It is fairly common to find the ureter on one or both sides double. The extent of this doubling varies much, from a few inches to nearly its entire length. The ureter always however becomes single before it reaches the bladder.

I have seen this doubling in 8 cases: in none of which, however, was it so extensive as in that described by Wood,[3] where it extended to within 1 inch of the bladder.

Many cases of abnormal ureters have been described by Coen,[4] Féré,[5] Longé,[6] Richmond,[7] Josso,[8] &c.

[1] *Morris*, as before.
[2] Brösicke, *Virchow's Arch.*, Nov. 1884, vol. xcviii. p. 338.
[3] Wood, *Path. Soc. Trans. Lond.*, vol. vii. p. 261.
[4] Coen, *Riv. Clin. di Bologna*, 1883, 3 s., iii. 708–719.
[5] Féré, *Progrès Méd.*, Paris, 1882, x. p. 70.
[6] Longé, *Marseilles Med. J.*, 1883, xx. 577–580.
[7] Richmond, *Journ. Anat. and Phys.*, 1884–5, vol. xix. p. 120.
[8] Josso, *Gaz. Méd. de Nantes*, 1883–4, ii. 123.

Thompson[1] records a kidney with double pelvis and ureter.

There can be no doubt that the list of single kidneys has been enormously, though wrongly, enlarged by the addition to it of many cases of deformed kidney; and although Hortolès[2] and many others carefully discriminate between the two forms, most writers do not make this distinction.

## VII. Renal Vessels (Abnormalities).

The common irregularities in size, number, position, and source are too well known and have been too often described to call for mention here.

Macalister[3] and others have done them full justice.

[1] Thompson, *Path. Soc. Trans.*, vol. vi. p. 267.
[2] Hortolès, *Mém. Soc. d. Sc. Méd. de Lyon*, 1882, xxi. pt. 2, 30.
[3] Macalister, *Journ. Anat. and Phys.*, vol. xvii. p. 250.

# RETAINED TESTES IN MAN AND IN THE DOG. By JOSEPH GRIFFITHS, M.A. (Cantab.), M.D. (Edin.), F.R.C.S. (Eng.), *Assistant to the Professor of Surgery in the University of Cambridge, and Pathologist at Addenbrooke's Hospital.* (PLATE VII.)

RETENTION of the testes in any part of their course from beneath the kidney to the scrotum is not uncommon in Man and in the domesticated animals. I propose to give here an account of the structure and functional powers of such retained testes; but, before doing so, I shall pass in review, as it were, the different positions in which these organs may be found persistent in different members of the mammalian group of animals.

In all vertebrates below mammals the testes are abdominal organs, and not, indeed, until we pass the more primitive order of mammals, namely, the monotremes, do we find that the testes leave their seat of origin in the abdominal cavity below or beyond the kidneys for an external subcutaneous position in the groin or perineum.

In most mammals the testes pass from the abdominal cavity along the hinder part of the ventral wall of the abdomen to reach the scrotum. The transition, or descent, as it is more commonly called, of these organs takes place in Man during the later months of intra-uterine life, and, as a general rule, the testes reach their destination, the scrotum, before birth. The complete descent may, however, be delayed until shortly after that event, or it may be for months or years.

In some mammals—the monotremes, the aquatic carnivora, the elephant, rhinoceros, and in certain others—the testes remain in the abdominal cavity throughout life, and there carry on their function.

In certain other mammals the testes are neither persistently abdominal nor persistently scrotal, the organs passing to and fro between the abdominal cavity and the scrotum. Among these are many of the rodents and insectivores, and in all of them

there is a period of *rut.* While the rutting season is at its height, that is, at a time when the testes are large and actively producing spermatozoa, the organs are in the scrotum or extra-abdominal; but, with the decline of the season, the testes dwindle and retire into the abdominal cavity, where they remain of small size until the return of the next period of rut.

Accordingly in the first (persistently scrotal) group, the testes having reached the scrotum acquire their full size and spermatozoa-producing powers; in the second (persistently abdominal) they retain their original position, and there attain their full size and spermatozoa-producing powers; in the last (to and fro) group, the testes leave the abdomen temporarily for the scrotum, and while they are in the scrotum acquire and retain their full size and spermatozoa-producing powers, losing it again when they retire into the abdomen.

Thus, in the last (to and fro) group, the testes may be said to be at one time in a state of *activity*, and at another in one of *inactivity*, the scrotal position being associated with activity, and the abdominal with inactivity.

The structure of the testes in these two states, namely, *inactivity* and *activity*, are well illustrated in the hedgehog (*Erinaceus europæus*), an animal that has a rutting season which is at its height in midsummer; but the functional activity of these organs is in complete abeyance during the winter months. In midwinter the testes are abdominal, resting just over the brim of the pelvis, of small size and firm consistency, and all the accessory sexual glands, *vesiculæ seminales* and prostate, are likewise small and firm (see fig. 1). In midsummer, on the contrary, the testes are scrotal (inguinal) in position, of twice, at least, the length and breadth they were in winter, soft and pulpy, the seminal tubules bulging wherever the tunica albuginea is cut through.

In the *inactive* testes the seminal tubules are only half, or even less, the diameter they attain in midsummer, and are not so closely packed together as when the testes are in full functional activity. Each tubule is at this stage a solid column of cells, there being no central lumen which, as well shown in figs. 3 and 4, is very large in the seminal tubules in midsummer. The *tunica propria* is perhaps thicker than natural. Lying

within this is a single layer of cubical epithelial cells with large round nuclei. In many of these cells there is a clear ring-like space around the nucleus. The central part of the tubule is occupied by polygonal cells which have no definite arrangement, but are massed together filling the lumen. These cells also have large round nuclei, and in many of them a clear ring-like space, similar to that in the peripheral layer of cubical cells, is present. No signs of spermatogenesis or spermatozoa could be detected in any of the tubules (see fig. 2).

In the summer the tubules are much larger. The epithelial cells are arranged thus: a continuous peripheral layer of cubical cells, then two or three layers of cells, the nuclei of which are in process of division, and innermost the radiatory bunches of spermatozoa. There is a large lumen occupied by spermatozoa and coagulated secretion (see fig. 4).

In the first group, in which Man is included, when the testes fail to reach the scrotum, from arrest in their course from the abdomen (which may be from some defect in the mechanism of descent[1]) though they grow to some extent at puberty, yet neither then nor at any subsequent period do they reach their full size and acquire their spermatozoa-producing powers.

We learn, therefore, that though in some animals the abdominal position is compatible with the full development and sperm-producing powers of the testes, yet that for some reason it is not so in the case of those animals in which they persistently or occasionally occupy the scrotum. The same remark applies to the inguinal region, for in animals in which the testes are naturally and persistently inguinal they become fully developed; whereas in those in which they are unnaturally arrested in the inguinal region, the functional, spermatozoa-producing, powers are not developed. In short, for the functional activity of the organ the testes must occupy the terminal part of the course which they are destined to traverse, though the reason of that is not very easy to determine. This subject I do not propose to discuss here.

[1] Failure in transition, or descent of the testes, has been referred by some to a congenital defect in the structure of the testes, which in consequence fail to stimulate the muscular mechanism of descent into activity, and by others to imperfections in the mechanism of transition, the organs themselves being healthy.

Failure in transition of the testes is usually unilateral, but sometimes it affects both sides; and the transition is said to be naturally later and more liable to defect on the right than on the left side. When the failure in transition is bilateral, as in one of the cases hereafter described (cryptorchid), then of course the question of the exact structure and functional powers of the organs is important. When one organ is fully descended (monorchid) and fully grown, as is well known, the person is as capable of reproducing his species as if he had two organs endowed with full powers. On the contrary, a person in whom both organs have failed to reach the scrotum, whether they were arrested in the iliac fossa, at the internal ring, in the inguinal canal, or just outside the external ring (a favourite situation) is, and the subsequent observations prove this, sterile, the testes being incapable of producing spermatozoa, and this although there is no indication of want of virility in the penis or general development of the individual. Indeed, in a person (cryptorchid) in whom both testes are arrested in any part of their course, all the manly characters, namely, broad shoulders, narrow pelvis, bearded face, &c., and the penis, are as fully developed as they are in a man whose testes are natural and in the scrotum. He has erection of the penis and emissions of secretion which, as will be shown later, is in all probability derived from the prostatic and other urethral glands, and is therefore devoid of spermatozoa.

Such a person (cryptorchid) is very different from the eunuch[1] deprived while young of his testes. In such the shoulders are narrow, the pelvis broad, and the face beardless, &c.—in those points approximating to the features of the female. In the eunuch also the external organs of generation remain small, the penis like that of a boy eight to ten years old, and the accessory sexual glands, namely, prostatic and Cowperian glands, remain small and otherwise imperfect.[2] How far erection of the penis is present in eunuchs, and also in eunuchoid persons in whom the testes remain small from disease and atrophy in early

[1] One deprived of his testes after attaining adult life possesses the male features, and is subject, for a time at least, to the same sexual influence as the entire and mature male.

[2] See paper by me on the "Prostate Gland," *Jour. of Anat. and Phys.*, vol. xxiv. p. 32.

life, is difficult to ascertain. This much, however, may be said, that in some eunuchoid persons (to this I draw attention in a subsequent paper, see page 221), sexual desire is present, and some get married. I have known one married eunuchoid person, but how far he had the power of erection, and what quantity of secretion he was capable of expelling, I was unable to ascertain, because he was unwilling to disclose to me any information upon this subject.

Hitherto this fact of sterility in cryptorchids has not been fully recognised, and thus it is, I believe, that persons are somewhat reluctant to accept the statement that the retained testes, though capable of giving impulse to the formation of the characteristics of the male sex during growth at puberty, are yet incapable of producing spermatozoa. Whatever may be the channel through which the testes exert this influence upon the growth of the body, whether it be by a reflex mechanism through the central nervous system, or by the influence of some as yet obscure secretion of the organs finding its way along the lymph channels into the circulation, it would seem that the general influence of the testes upon the growth of the body is distinct from its spermatozoa-producing power; and further, that the exercise of the former function necessitates less expenditure of energy than the production of sperm-cells which may be regarded as the most highly differentiated and power-giving cells in the animal kingdom.

Some observers state they have found the retained testes fully formed, have detected spermatozoa in their secretion, and have also seen evidences of the production of spermatozoa in the epithelial cells of the seminal tubules. But in by far the majority of cases hitherto reported, spermatozoa were not found in the seminal tubules or in the secretion lodged in the tubules of the epididymis or in the cavity of the corresponding vesicula seminalis. To this subject I shall revert later.

## Retained Testes in Man.

With regard to the retained testes in Man, the following examples which I have collected and examined illustrate very well the different structural conditions met with. Four of the

specimens were removed from persons (monorchids) in whom the opposite testis was fully descended and natural, the fifth was from a man (cryptorchid) in whom the condition was symmetrical, both organs being situated just outside the external abdominal ring.

*Example I.*—A specimen (1065) in the Pathological Museum of the University of Cambridge, the description of which in the catalogue is as follows :—

"Right testicle situated at the external ring. It [testis] is small though plump, and the epididymis is disproportionately large. There is a sac of a congenital hernia, from which a blue glass rod has been passed into the tunica vaginalis. The left testicle is of natural size, and occupied the natural position in the scrotum. On microscopical examination, after the specimen has been some months in spirit, large cells, like sperm-cells, are found in the epididymis on both sides, but spermatozoa in the left only."

The body of the *right* testis measures 3 cm. in length by 1·8 cm. in breadth; whereas that of the left, which was fully descended into the scrotum, measures 4·5 cm. in length by 3 cm. in breadth. A section of the *right* testis shows the seminal tubules to the eye, as in a normal organ, but they are more distinct, and, therefore, more easily seen, the inter-tubular connective tissue being relatively increased.

Under the microscope the seminal tubules in this right testis are found to be reduced to at least one-half their natural size, and the inter-tubular connective tissue is relatively increased. This inter-tubular connective tissue is composed, in the main, of spindle-shaped connective tissue cells, with but little intervening fibrous matrix; and in it there are hardly any traces of the peculiar *interstitial* cells frequently found in the normal and full-grown organ. The seminal tubules are, in addition to being reduced in size, altered in their structure. The tunica propria is much thickened, and, as seen in transverse section, forms a sort of collar round the tubule. This tunic is composed, as in the natural condition, of two or more layers of flattened connective tissue cells, with but little intervening fibrous matrix, the thickening seen in the specimen being mainly due to the formation on the side next the lumen of a layer of newly-formed, almost transparent, fibrous tissue, with only one or two flattened cells embedded in the matrix. This layer of tissue I have often found, and always in the same position, in other cases of atrophy. The epithelial cells in the seminal tubules are greatly reduced in numbers, and in the majority of instances the cells form only a single layer which lines the thickened and altered tunic and which encloses a small central lumen. The cells differ from the normal, inasmuch as they are of columnar shape, with a broad base and narrow free extremity which projects into the interior of the tubule and bounds the central lumen when present. In each of these cells a round or ovoid nucleus

may be seen occupying a position near the basal or attached end of the cell; and in each the protoplasm is finely granular, with a tendency to fibrillation in the long axis of the cell. Here and there among these cells, smaller cells, with irregular outlines and indistinct nuclei, may be seen. In a few of the tubules the epithelial cells are not so regularly arranged, but they are of irregular outline, and are massed together, as it were, there being no central lumen. In none of these tubules is there any evidence of spermatogenesis in the epithelial cells, and there is no evidence of spermatozoa in the interior of the tubules. In short, the seminal tubules are small, their tunica propria is thickened, and the epithelium is reduced to a single layer of columnar-shaped cells.

*Example II.*—This specimen was removed during the operation from a young man aged nineteen years, for the radical cure of hernia. The body of the testis is flattened and elongated, measure 4·5 cm. in length by 2·5 cm. in breadth, and 2 cm. in thickness; and on section the seminal tubules are, as in Example I., more distinct than natural. Under the microscope this specimen showed precisely the same structural changes as the preceding, with the exception that the tunica propria is not so much thickened, the fibrous transparent layer already noted being almost absent. There are no spermatozoa in any of the tubules, and no traces of spermatogenesis in the epithelial cells which in most of the tubules are elongated and of columnar shape, as seen in fig. 7, taken from a section of this specimen.

*Example III.*—This was removed from a man, aged thirty-four years, also in the operation for effecting a radical cure of the associated hernia. The body of the testis is small and also flattened; it measures 3·5 cm. in length by 2·5 cm. in breadth, and 1·5 cm. in thickness; and on section the seminal tubules are seen to be rather more distinct than natural. Under the microscope the tubules are like those in Example I., but there is also some increase of the inter-tubular connective tissue which binds the tubules together more firmly than usual.

*Example IV.*—This specimen was obtained from a man forty years of age, married, but without issue. Both testes had barely escaped through the external abdominal rings, and were lying in the inguinal region, the scrotum being small and empty. Each was associated with a hernia. The *right* testis was removed in the operation for radical cure by Dr Carver, to whom I am indebted for the specimen. The man was strong and well built, the shoulders broad, and the pelvis narrow, though the hair on face and pubis was scanty. The penis was of natural size.

The *right* testis is small, round, and somewhat flaccid; it measures 2·5 cm. in length by 2 cm. in breadth, but in other respects it seemed natural. The epididymis is small, but large in proportion to the body of the testis, from which it is distanced about 1 inch, consequent on the stretching and yielding of the intervening tissue (fig. 6).

Under the microscope the seminal tubules are seen to have undergone similar changes to those described in the preceding cases, and

even more pronounced; for in some tubules the epithelium has almost entirely disappeared, and the tunica propria has been greatly thickened, so that these tubules are transformed, more or less completely, into rods of fibrous tissue. The remaining epithelial cells are of irregular size and shape, and are without any definite arrangement. In some of the tubules the epithelium is reduced to one or two cells, and in some it has completely disappeared. The inter-tubular connective tissue, which is mainly composed of fusiform cells, is relatively increased, owing to the diminution in the size of the seminal tubules. The pronounced changes observed in this specimen were probably produced by the presence of a truss which he had worn for many years.

*Example V.*—The *right* testis, removed from a boy aged 12 years, was found just outside the external abdominal ring. There was apparently no gubernaculum extending to the scrotum which was on that side small. The body of this, the *right* testis, measures 14 mm. in length by 8 mm. in breadth, whereas that of the *left* testis, which was properly descended and in the scrotum, measures 15 mm. in length by 10 mm. in breadth. The right epididymis is small and apparently deficient in its lower part. The right vas deferens is short and slender, but otherwise natural. In this, as in similar cases, the tunica vaginalis is large and the processus vaginalis is patent, opening freely above into the peritoneal cavity and below into the capacious tunica vaginalis. Under the microscope the seminal tubules are seen to be small, and filled with small epithelial cells as they are before puberty.

This specimen, which is the only one removed from a boy that I have had an opportunity of examining, is similar, both in external appearance and internal structure, to the undescended testis in a puppy (see vol. xxvii. p. 486), and to the testis replaced in the abdomen in a young dog and examined before the onset of puberty (vol. xxvii. p. 494).

The thickening of the *tunica propria*, which, as seen in the above specimens, seems to have taken place on the inner surface of the original tunic, and between it and the outermost epithelial cells, has been supposed by MIFLET (6) to be produced by the receding epithelium, and to be an instance of epithelial cells transforming themselves into connective tissue cells. I have, however, not been able to confirm this view, and from the fact that this layer of connective tissue is quite distinct and separable from the epithelial cells of the tubule, I scarcely think such a transformation of the epithelial cell of the tubule takes place.

Again, it is of interest to note that the epithelial cells of the tubules acquire a columnar shape. This shape is, as I have shown elsewhere, gradually acquired as the cells diminish in number, the first to disappear being the central cells, then those next to them, leaving ultimately only the representatives of that

continuous single layer of cubical cells found within the *tunica propria* in a normal seminal tubule. Thus the columnar cells noted here are the representatives of that peripheral layer of cubical cells which in the normal tubule give rise to the inner or the spermatozoa-producing cells.

## The Retained Testes in the Dog.

Retention of one testis, either in the abdominal cavity or in the groin, is not of uncommon occurrence in the Dog. I have found during the past year no less than four examples, in each of three of which the right testis was retained in the groin, the left being fully descended and occupying the scrotum, and in the fourth the left testis was found hanging down into the pelvis.

The retained organ was in each case of small size, and very like the testes of a young puppy, the epididymis being disproportionately large to the body of the testis. There was no secretion in the tubules of the epididymis (vesiculæ seminales are absent in this animal), and, as will be presently shown, there were no spermatozoa in the tubules of the testes. A description of one of the cases will suffice, as they were all alike.

*Example.*—A dog, three to four years old. The right testis was found in the groin, just beyond the external abdominal ring. It was small, and measured 15 mm. in length by 12 mm. in breadth. The left testis, which was in the scrotum, was of full size, and its body measured 20 mm. in length by 15 mm. in breadth (see figs. 9 and 10). With the naked eye the only difference observable being that the tubules were more apart, and, therefore, more distinct in the retained organ.

Under the microscope the right testis shows that the tubules are not more than one-half the size of those in the left or descended organ. In each tubule the tunica propria is somewhat thickened, the cells polygonal, abundant, and completely filling the tubule. This difference from the normal is very marked (see further a paper by me in the *Journal of Anatomy and Physiology*, vol. xxvii. p. 483). No evidence of spermatozoa or spermatogenesis.

The preceding observations are confirmed by a series of experiments I performed on the Dog, and published in the paper above referred to. In these I replaced the testis, without injuring the organ itself or the structures of the cord, in the abdominal cavity in young and in full-grown dogs. The results obtained were the following:—

(1) When the testicle of a young animal is replaced in the abdomen, it undergoes but little change, growing somewhat, but not so much as the undisturbed organ, until the onset of puberty.

(2) A testicle so replaced after the onset of puberty continues to grow to some extent, though but little.

(3) The testicle of a full-grown animal when replaced in the abdominal cavity soon dwindles to two-thirds or one-half its natural size, and after a short time presents precisely the same structure as that which is found in the replaced testicle of a young animal above noted.

In each case the epithelium is reduced to a single layer of columnar, tapering cells, with the pointed ends projecting into and filling the lumen more or less completely. The protoplasm of the cells is fibrillated in the long axis of the cells; and the nuclei are small and round, and placed near the basal, broad end of the cells. In none of these tubules are there any traces of spermatogenesis seen in the epithelial cells and no spermatozoa in the interior of the tubules (see fig. 11).

Thus, both in Man and in the Dog, the *retained* testes are of small size, and they alike present a definite structure that is almost, though not quite, peculiar to them; and they are not in that state which is fitted for the production of spermatozoa.[1]

HUNTER (1) expressed the view that the *retained* testis were, *ab initio*, imperfect in their structure, and that it was owing to this imperfection that they failed to stimulate into activity the mechanism of descent, and thus they remained undescended. CURLING (2) stated that this was not the case in the majority of instances, and he considered that the testes when retained are in structure like the testes before the onset of puberty. That this view, however, is not correct is shown by a comparison between the structure of the retained and of the undeveloped organ. In the former, as we have seen, the tunic of the tubules is thick, and the epithelium consisting, as a rule, of a single layer of columnar cells; whereas in the nominal condition of the child the tubules consist of a solid rod of small polygonal cells surrounded by a thin tunica propria. GODARD (3), who is followed by MONOD and ARTHAUD (4), maintains that the *retained* testes acquire their natural structure; but he specified that their secretion does

[1] In the testis of the aged, the epithelium assumes much the same character. See a paper by me ("Structural Changes observed in the Testicles of Aged Persons"), *Jour. of Anat. and Phys.*, vol. xxvii. p. 474.

not contain spermatozoa. A careful microscopical observation would, however, have shown him that although, to outward appearance, the testis in the two cases (descended and retained) are similar, the intimate structure is very different.

FOLLIN and GOUBAUX (5), with whom I concur, found that, both in Man and in the domesticated animals, the testes were not only of small size, but the seminal tubules were atrophied and incapable of producing spermatozoa.

## CONCLUSIONS.

1. The *retained* testis in Man and in the domesticated animals is of small size, and the seminal tubules, though smaller, are more distinct owing to the disproportionate amount of inter-tubular connective tissue.

2. The walls of the tubules are thick from the formation of fibrous tissue on the inner surface of the tunica propria; and the epithelium is scanty and columnar, and there are no traces of spermatogenesis.

3. The testes in cryptorchids, though they are incapable of producing spermatozoa, are yet capable of exerting that influence which the natural testes exert upon the development of the penis and the growth of the body.

4. The function of the testes, namely, that which influences the growth of the body at puberty, is distinct from that of the production of spermatozoa, the latter necessitating a more specialised development of the tubules of the gland than the former.

5. The testes do not acquire their full (spermatozoa-producing) function, except at the furthermost point of descent from their primary position.

## LIST OF REFERENCES.

(1) HUNTER, *Animal Economy.*

(2) CURLING, *Diseases of the Testes*, 4th ed.

(3) GODARD, *Rech. sur la Monorchid et Cryptorchid chez l'Homme.*

(4) MONOD et ARTHAUD, "Étude des Alterations du Testicule Ectopique," *Arch. Gen de Med.*, 1887.

(5) FOLLIN et GOUBAUX, "De la Cryptorchidie chez l'Homme et les principaux Animaux domestique," *Mem. de la Soc. de Biol.*, 1855.

(6) MIFLET, *Langenb. Arch.*, Bd. 24, s. 399.

## DESCRIPTION OF PLATE VII.

Fig. 1. Diagrammatic representation of the testes of a hedgehog (*Erinaceus europœus*) in midwinter, when sexual activity is in abeyance. *ep*, Epididymis ; T, testis ; *v.d.*, vas deferens (nat. size).

Fig. 2. Transverse section of one of the seminal tubules in the testis of a hedgehog at midwinter. (*a*) Tunica propria consisting of single layer of flattened tissue cells ; (*b*) continuous layer of cubical cells lining tunica propria ; (*c*) polygonal cells with altered nuclei and finely-granular protoplasm occupying the centre. × 300.

Fig. 3. Diagrammatic representation of testes of hedgehog in midsummer, when sexual activity is at its height (nat. size).

Fig. 4. Transverse section of one of the seminal tubules in the testis of a hedgehog at midsummer, when sexual activity is at its height. (*a*) Tunica propria as in fig. 2 ; (*b*) single layer of cubical cells lining tunica propria ; (*c*) spermatogenetic cells, within which are the clusters of spermatozoa. The lumen is occupied by coagulated secretion, in which there are no spermatozoa.

Fig. 5. Diagrammatic representation of a normal full-size testis of an adult man (nat. size).

Fig. 6. Diagrammatic representation of retained testis in Example II. showing the small size of the organ, and the distance intervening between the epididymis and the body of the testis.

Fig. 7. A transverse section of a seminal tubule in the testis of Example III., showing the slightly thickened tunica propria. (*a*) The single layer of columnar slightly fibrillated tapering epithelial cells lining the tubule. × 350.

Fig. 8. Transverse section of a seminal tubule taken from the retained testis in Example II. In it the *tunica propria* is composed of an outer (*a*) thin layer of flattened connective tissue cells with but little intervening fibrous matrix, and an inner (*b*) thick layer of an almost transparent finely-fibrillated connective tissue, in which there are hardly any nuclei of connective tissue cells. The epithelium (*c*) is reduced to a few cells of irregular size and shape, with round nuclei and highly granular, though not fatty, protoplasm. × 350.

Fig. 9 and 10. The testes, right and left respectively, of a dog ; the former was natural and in the scrotum, but the latter small and retained in the groin (nat. size).

Fig. 11. Transverse section of a seminal tubule taken from the retained left testis (fig, 10), showing the tunica propria (*a*) more or less normal, and the epithelium reduced to an almost single layer of columnar tapering and fibrillated cells converging towards the centre, much the same as in fig. 7.

# THE CONDITION OF THE TESTES AND PROSTATE GLAND IN EUNUCHOID PERSONS. By Joseph Griffiths, M.A., M.D., F.R.C.S., *Assistant to the Professor of Surgery in the University of Cambridge, and Pathologist at Addenbrooke's Hospital.* (Plate VIII.)

I have lately had an opportunity of examining two *Eunuchoid* persons; I mean persons in all respects like eunuchs except that in them the testes, though small, are in the scrotum. In eunuchoid persons the frame is usually big, the shoulders narrow, and the pelvis broad; the face beardless, the neck round and plump, and the voice often high pitched; the breasts large; the penis and scrotum small, being not larger than they are in a boy eight to ten years of age.

The first case I saw presented all the above features; and, on examining his prostate gland through the rectum with the finger, I could discern hardly any gland substance, but simply some thickening behind the urethra in the natural situation of the gland. This man was about thirty, married, but without issue. I ascertained that he was in the habit of having connection, but could obtain no further particulars.

The second case I examined *post-mortem.* In this also the eunuch-like features were well marked, and the testes, which I removed together with the rest of the genital apparatus, were small and undeveloped. He died at the age of twenty-one years from pulmonary phthisis.

The bodies of both testes were of natural shape, but measured only 18 mm. in length by 10 mm. in breadth, the body of a normal testis being about 40 mm. in length by 30 mm. in breadth. The epididymes were also small, but large in proportion to the bodies of the testes (see figs. 1 and 2). The vasa deferentia, vesiculæ seminales, and prostate gland were also small; the last being hardly more than a third of its natural size.

Above each testis and occupying the lower part of the spermatic cord, where the pampiniform plexus of veins is most

marked in a healthy testis, was a large, ovoid, compact mass of fat. Such an abnormal accumulation of fat has been present in all the specimens of like kind that I have seen. Curling notes a similar condition in undeveloped testes.

To the naked eye a section of the TESTIS shows a compact and fibrous structure which is not at first sight unlike that of the testis of a young boy; but, under the microscope, the seminal tubules are seen to be little more than solid rods of fibrous connective tissue, there being in the middle of each only a narrow fissure occupied by atrophied epithelial cells, or cell-débris (see fig. 3). The tunica propria of each tubule, thus altered, consists of two layers, an *outer* and an *inner*. The *outer* thin layer or tunic is composed of a single layer of flattened connective tissue cells with but little matrix; this layer being both in position and structure like the tunica propria of the natural tubule. The *inner* and thicker layer is composed of an almost transparent fibrous tissue with slightly fibrillated matrix and but few connective tissue cells; this occupies the place of and would seem, as in other cases of atrophy, to have been formed at the expense of the receding and dwindling epithelium. Here and there are a few tubules in which the centre is seen to be occupied by a number of large closely-packed polygonal cells with round nuclei containing small granules. In these, however, the transparent fibrous formation within the tunica propria is pronounced and like that in the tubules the epithelial cells of which are more nearly absent. These altered tubules are closely packed and bound together by fibrous connective tissue in which there are many spindle-shaped cells with a few large blood-vessels. In the corpus Highmorianum the tubules and channels of the rête are embedded in fibrous connective tissue as in the normal testis; but the ducts connecting the seminal tubules with the rête are more separate, and therefore more obvious, than natural (see fig. 4). These connecting ducts are lined by a single layer of sub-columnar epithelial cells which are continuous with the cubical cells lining the channels of the rête on the one side and with the cells of the seminal tubules on the other. Here there are numerous large venous channels.

The EPIDIDYMIS was naturally formed, and large in proportion

to the body of the testis. Under the microscope some lobules in the globus major appear natural, and the individual tubules, though small and contracted, are lined by a single layer of tall, ciliated, columnar cells, the lumen being small and empty. Whereas in other lobules they are much altered, the tubules being small and the epithelial-lining consisting only of a single layer of sub-columnar non-ciliated cells, and the muscular coat thin and in some places absent, being replaced by fibrous connective tissue which passes without any line of demarcation into the surrounding inter-tubular connective tissue. This inter-tubular connective tissue is large in amount, dense and fibrous, binding the altered tubules firmly together (see fig. 5). In none of the tubules can any spermatozoa be seen. The abnormal lobules much resemble lobules which have undergone the changes consequent on the inflammatory process.

The PROSTATE was small, tough, and fibrous. With the naked eye it could be seen that it contained some gland tubules, though they were few and scanty. The glandular tubules, as seen under the microscope, resemble the normal lobules, except that they are more *en evidence*, being few, and that the epithelial cells lining them are small and in two or three layers, the cells in a normal tubule being in a single layer and long and slender. The inter-tubular connective tissue was much more fibrous than natural, and the unstriped muscle-fibres were less developed.

The VESICULÆ SEMINALES were also small, being not larger than those of a young boy.

I have examined a similar specimen (of testes) in the collection of the Cambridge Pathological Museum, and found that they present the same structure as those I have described above. Other specimens, which are evidently of the same nature, may be seen in other museums.

I may here add that this state of the testes and sexual organs is not unfrequently met with in idiots, as Curling points out. I have seen it only in one case, but the number of idiots examined by me was very small.

This condition of the testes has hitherto been regarded as the result of simple arrest of growth, the organs retaining their pre-puberty structure. To the naked eye the body of the testis is indeed very like that of the testis of a boy both on the

exterior and on section; but in internal structure the two are very different. In a boy the seminal tubules are solid rods of small polygonal cells, lying within a thin tunica propria; whereas in the eunuchoid person the seminal tubules are solid rods of fibrous connective tissue, with only a narrow fissure in the centre, occupied by a few epithelial cells, with débris. Besides, the epididymis in the eunuchoid persons is actually much larger than in the child, and in the latter the tubules are lined by small, cubical, non-ciliated epithelial cells, whereas in the eunuchoid some are natural and others altered. These peculiarities, therefore, in the structure of the body of the testes and the epididymis in the eunuchoid show that the condition is distinct from that of the young boy.

Further, the state of the body of the testis in eunuchoid persons is different not only from that of the testis of a boy, but also from that of the undescended or imperfectly descended organ. For in the testis of the eunuchoid the seminal tubules are almost solid rods of fibrous connective tissue, having usually a fissure-like lumen, containing atrophied epithelial cells or only debris of cells; whereas in the undescended organ, or, indeed, in the organ replaced from the scrotum in the abdominal cavity, the seminal tubules are lined by rods of epithelial cells which are in a single layer, numerous, long, and tapering, with their broad ends at the periphery of the tubule, and their narrow ends projecting into and almost filling the lumen.

The testes in the eunuchoid do in many respects, however, resemble very closely the testes which have suffered from attacks of inflammation in early life or even at puberty, inasmuch as the bodies of the testes are small, the seminal tubules are represented by almost solid rods of fibrous tissue, and the inter-tubular connective tissue is increased in amount and is fibrous. Besides, an almost identical state of the testes may be produced in puppies by tying the spermatic artery and veins in the groin.[1]

With regard to the manner in which this eunuchoid condition arises, it may be asked whether it is due (1) to an inherent want of growing power in the seminal tubules, (2) to interference with

[1] I propose shortly to publish some experiments on interference with the vascular supply of the testes, which illustrate these and other points.

the normal growth of the tubules from the result of some changes in the nerves or blood-vessels of the organ, or (3) to the destructive influence of some morbid process in the organ itself.

It is true that in many idiots this condition of the testes is met with, and it is interesting to make a sort of comparison between the structure of the seminal tubules and that of the grey matter of the cerebral hemispheres of such persons. In each organ the special cells of the part are few in number and but ill developed, while the neuroglia in the one and the inter-tubular connective tissue in the other are abundant. The condition of parts in both organs seems to favour the view that the changes result primarily from an inherent want of advancing (growing) power, and consequent degeneration in the special cells, which, of course, dominate growth; and coincident with the want of growing power in them is an excessive growth in the lower, or connective tissue. Thus we may suppose that the testes are during early life of natural structure, and that some time before puberty the cells of the seminal tubules come to the end of their growing power. After this the cells would dwindle rather than maintain their ground, and in time disappear, the connective tissue at the same time increasing. It is obvious that this arrest or failure of growth in the seminal tubules takes place before puberty, from the fact that the individual in his growth acquires the characteristics of that of the eunuch who had been deprived of his testes while young. But how early it may occur, whether before or after birth, remains as yet obscure.

It may, however, be held that the failure results from some disturbance in the central nervous system, or some failure of the arteries to grow at puberty. It is only when the condition occurs in idiots that it may, with some show of reason, be held that this arrest of growth is due to any nervous lesion; but as the condition is met with in otherwise healthy persons, we are scarcely warranted in referring it to a defect in the nervous system. Failure in the due development of the arteries during childhood is not, perhaps, an unlikely cause, seeing that a similar condition is producible, with great certainty, by interfering with the vascular supply of the organ through ligation of both spermatic artery and veins in the groin.

Again, though this condition is like that induced after an attack of inflammation in the body of the testes of a boy, or even in a young man during puberty, yet the affection is always bilateral, whereas inflammation is usually unilateral, one testis only being thus affected. For example, in case of mumps followed by orchitis, the inflammation is usually confined to one side, and only in a small minority of cases is the change so profound as to produce destruction more or less complete of all the seminal tubules.

Before concluding I would refer to the virile power of eunuchoid persons. No doubt they have erection of the penis, which function, as is well known, is ordinarily in all persons present at birth, and does not depend upon the full growth of the testes. No doubt, also, during connection a certain amount, though small, of secretion, derived probably from the urethra and its glands, is expelled. It is, however, not augmented by a supply from the testes where none is formed. Therefore the secretion is devoid of spermatozoa, and the individual is sterile.

### *Conclusions.*

1. In eunuchoid persons the testes are of small size and almost entirely composed of fibrous tissue, the seminal tubules being represented by fibrous rods with fissure-like lumina containing atrophied epithelial cells. Although thus altered, the testes retain their normal shape and form.

2. The epididymes are large relatively to the bodies of the testes, and the tubules in most of the lobules of the globus major are natural, the tubules in some few lobules being altered as if by chronic inflammation.

3. The prostate gland is small, tough, and fibrous, and the glandular tubules are but few in number and but imperfectly developed. The vesiculæ seminales are also of small size, and devoid of any secretion in their interior.

4. Where the testes lose their power of growth, from whatever cause, the individual develops at puberty like a eunuch deprived of his testes in early life. Such a person I have, therefore, called *eunuchoid*.

## DESCRIPTION OF PLATE VIII.

Figs. 1 and 2. Diagramatic representation of testes and epididymes of a eunuchoid person. (*a*) Body of testis; (*b*) epididymis; (*c*) mass of fat in lower part of spermatic cord. Natural size.

Fig. 3. A section of the seminal tubules, showing their transformation into rods of fibrous tissue with fibrillated matrix. The narrow fissure-like lumen is occupied with atrophied epithelial cells. × 250.

Fig. 4. Section of straight ducts with their branches at the junction of the tissue of the corpus Highmorianum with that of the body of the testis. The ducts are lined by sub-columnar epithelial cells, but their branches are filled with smaller polygonal-shaped cells.

Fig. 5. Section of natural tubules in lobule of the epididymis, showing columnar epithelial cells bearing cilia.

Fig. 6. Sections of altered tubules in epididymis. They are much reduced in size, and lined by sub-columnar non-ciliated epithelial cells.

# THREE PROJECTION DRAWINGS OF THE BRAIN

By T. Stacey Wilson, M.D. (Edin.), M.R.C.P. (Lond.),
*Physician to the Birmingham General Hospital.*

The preparation of the accompanying figures of the brain was undertaken in order to demonstrate the relationship which the sensory conducting paths between the cortex and the crura cerebri would bear to the (known) motor paths if the Rolandic area had sensory as well as motor functions. The author knew of no diagram which gave the position of the internal capsule relatively to the convolutions, and he therefore undertook the preparation of the accompanying figures, in the belief that figures of this description will prove of considerable value both to the clinician and the physiologist.

The aim of the drawings is to show at a glance the relationship which the internal structures of the brain bear to the convolutions upon its surface. With this end in view, the outline of the internal structures are in the figures projected upon the surface. This projection has been made in three different directions in the three drawings, viz., (1) vertically, showing both hemispheres; (2) laterally, in a lateral view of the left hemisphere; and (3) at an angle of 45° with the vertical. In this figure the right hemisphere is shown as viewed from a direction midway between the horizontal and the vertical line.

*Method.*—The method of preparation of the drawing was as follows:—

A brain was carefully removed, and hardened by means of Müller's solution. Tubes were tied into the vessels of the circle of Willis, and the solution was circulated through the brain at intervals for three days. The hardening was completed by allowing the brain to remain in Müller's solution for some months. The injection was carried on under a pressure of about 12 or 18 inches of water. When hardened, the brain was cut into sections of about ¼ of an inch in thickness. This was done several years ago, and I was fortunate in being ably assisted by

Dr Ebenezer Teichelmann, who was then studying medicine in Birmingham, but is now practising in Australia. Each of the

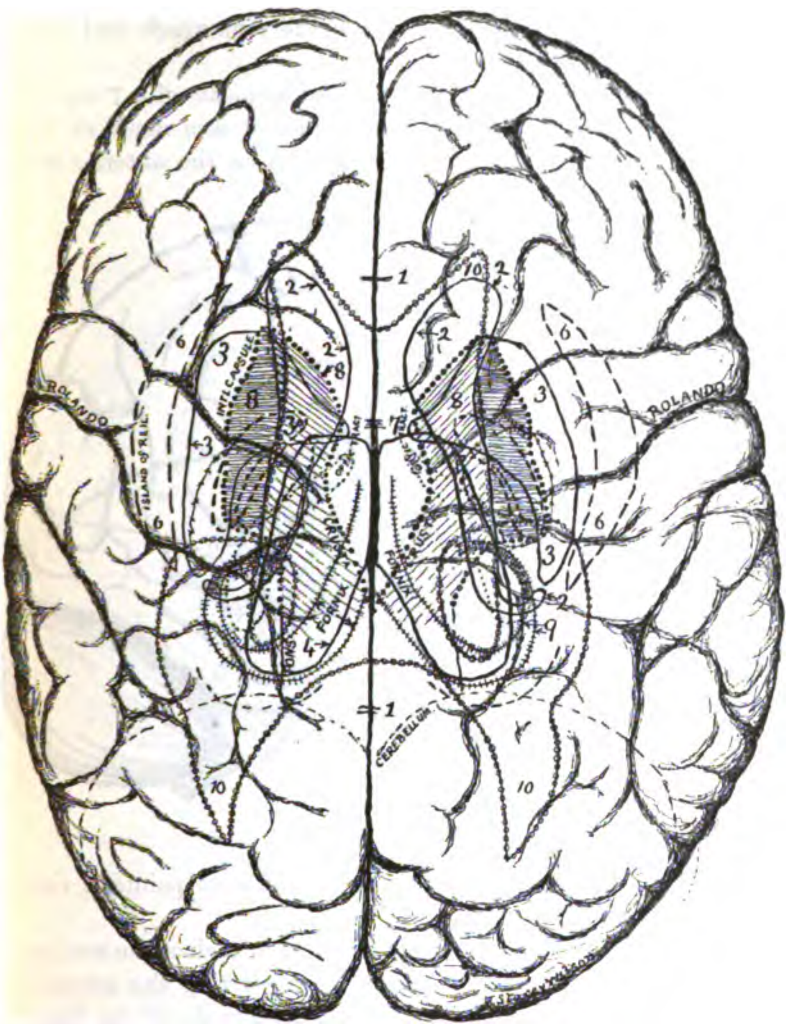


Fig. I.

sections was taken separately, and pins were inserted into the deeper sulci. The sections were then piled up accurately upon

one another, so as to reproduce the configuration of the brain, and the whole was photographed from each of the three points of view above mentioned. The photographs were enlarged to natural size. The course of the main sulci was clearly shown in the photographs by the situations of the pins which had been inserted into the individual sections.

The sections were then separated, and by means of a T-square and drawing-board accurate measurements were made of the maximum width of the various structures on the anterior face

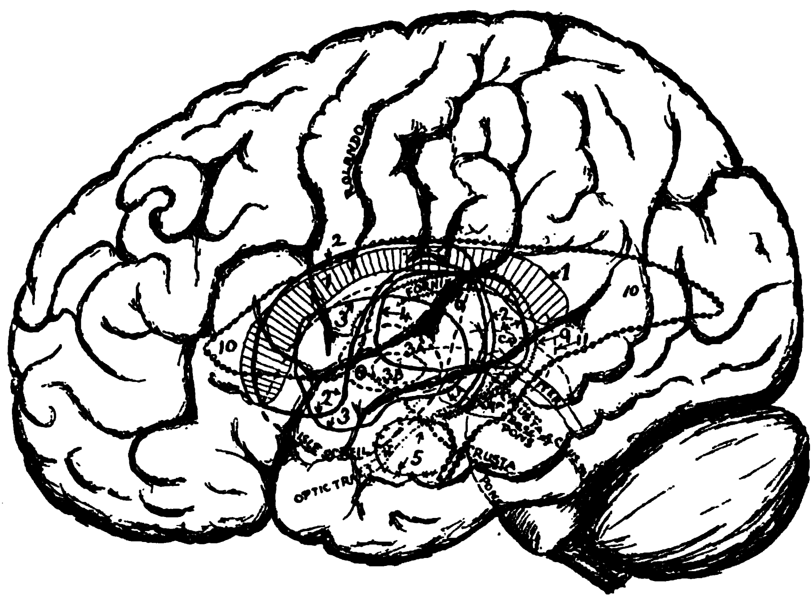


Fig. II.

of each of the sections from the three different points of view above mentioned.

The relative situation of the structures in each of the sections was thus obtained, and, by means of transferring the measurements to the section shown in the photographs of the brain, their relative positions in the brain was obtained. For the larger structures, the measurements obtained were sufficient to determine their outlines accurately; but with smaller structures, such as the putamen of the lenticular nucleus, they were not

sufficient, and special dissections were therefore made in order to determine the outline of these structures when viewed from above, from the side, and at an angle of 45° to the vertical. As a matter of convenience, it was found better to have the photographs enlarged to twice the natural size, in order to make the drawings more clear.

These photographs, and the drawings upon them, were then copied mechanically in outline, and reduced by photography to the size desired for publication.

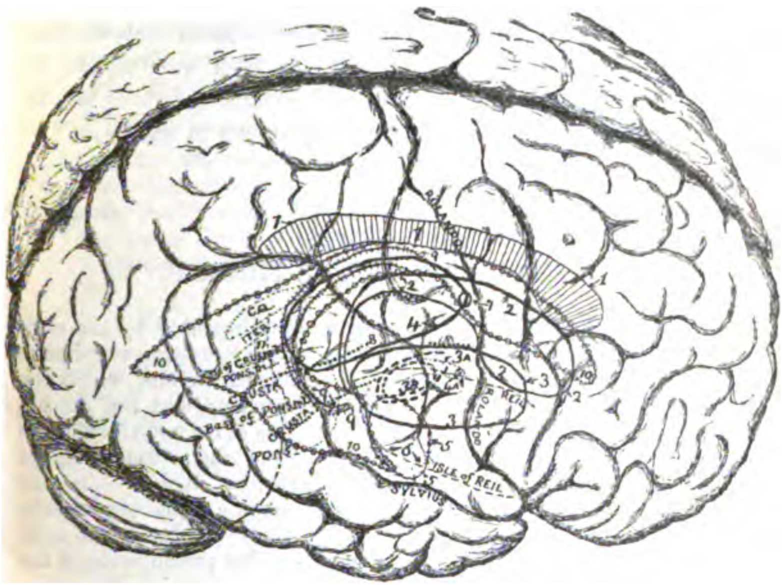


Fig. III.

——, Caudate and lenticular nuclei and optic thalamus ; -----, putamen ; ........, optic tract ; -x-x-x-, nucleus anterior to pes hippocampi ; ......., internal capsule and crusta ; +++++, fornix ; -•••••-, lateral ventricle.

*Accuracy.*—Although great care was taken with regard to the removal and hardening of the brain, there has been a slight amount of relative distortion, as is shown by comparing the position of the tail of the caudate nucleus and other structures on the two sides of the brain in the vertical view, fig. I.

The thickness of the sections is another cause of slight inaccuracies in outline, although in many instances this was

overcome by means of the supplementary dissections before mentioned.

The only structure whose outline was not properly determined in this way was the nucleus of grey matter (No. 5) which lies below the lenticular nucleus, and contiguous to the pes hippocampi.

In the vertical view, the measurements show that this nucleus on the left side is larger than on the right, but they do not sufficiently determine its exact outline. The ends of the two divisions of the putamen, as seen in the vertical view, ought perhaps to be represented as rather more pointed than they are.

In the brain from which these drawings were made the descending horn of the lateral ventricle extended further forward on the right side than on the left, as is shown in fig. I.

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## EXPLANATION OF THE FIGURES.

In all three figures the same structure is represented by the same kind of line, and for the sake of clearness certain structures are shaded. Thus in fig. I. the main portion of the internal capsule, which lies between the upper part of the lenticular nucleus and the caudate nucleus, is shaded with fairly close lines. The outer boundary of the capsule is, of course, an arbitrary line. The line taken was the highest point, where the capsule touches the lenticular nucleus—*i.e.*, the upper and internal edge of this nucleus as seen in a transverse section. The difference in the course of this line on the two sides is due to an error in drawing. The left side is accurate. The prolongation of the capsule inwards to form the genu and its continuation into the crusta of the crura cerebri are shaded faintly with sloping lines. These two tracts are shown as passing into the pons, and finally under the cerebellum. In the other two diagrams the corpus callosum is shaded with parallel lines.

The detailed description of the figures is as follows :—

### Fig. I.

1. Corpus callosum: only its anterior and posterior limits in the middle line are marked.
2. Caudate nucleus; marked by a thick line.
3. Lenticular nucleus; a thick line.

*3a*, *3b*. Two divisions of the putamen of the lenticular nucleus; marked by a thick broken line.

4. Optic thalamus; a thick line.

4a. External geniculate body and optic tract; fine dotted line.
5. Grey nucleus below lenticular nucleus and anterior to pes hippocampi; marked by a moderately thick crossed line.
6. Outline of the grey matter of the island of Reil; moderately thick broken line.
7. White commissure: situation only marked in the middle line.
8. Internal capsule; marked by thick dotted line. Its outer and upper part between lenticular nucleus and caudate nucleus is shaded darkly. Its lower portion and the crusta of the crura cerebri are shaded faintly.
9 and 9a. Fornix; thin crossed line. Its posterior portion and its descending pillars only are shown. Its descending pillars in the descending horn of the lateral ventricle are not distinguished from the fimbria or fascia dentata.
10. Lateral ventricle; marked by a beaded line. Its descending horn is, of course, marked as crossing (under) the outer boundary of its central part, and on the right side under the fornix. The boundary given marks its extreme outer and inner boundaries in each section.
11. Marks the situation, for a short distance, of the grey matter of the tænia hippocampi in the descending horn of the lateral ventricle; it is marked by a thin broken line.

FIG. II. Numbers and lines as before, viz.—

1. Corpus callosum (shaded).
2. Caudate nucleus (thick line).
3. Lenticular nucleus (thick line).
3a, 3b. Putamen of nucleus (thick broken line).
4. Optic thalamus (thick line).
4a. External geniculate body and optic tract (thin dotted line).
5. Nucleus below corpus striatum (moderately thick crossed line).
6. Island of Reil (moderately thick broken line).
7. White commissure (in mesial plane).
8. External capsule and crusta (thick dotted line).

The lower boundary only of the internal capsule is marked, its upper one being, of course, indefinite, and radiating out in a fan-like manner upwards. Its upper and posterior boundary is at the spot where the inter-parietal sulcus joins the fissure of Sylvius, and along a line between this point and the termination of the upper boundary of the crusta, as shown in the drawing. Owing to the lateral position of the crusta, its extreme upper limit is much higher, from this point of view, than its upper limit in the middle line. This latter boundary corresponds, of course, with the lower limit mesially of the tegmentum and grey matter below the aqueduct of Sylvius, which is marked in this diagram by the words "base of crus in mid. line." The situation of the corpora quadrigemina and the aqueduct of Sylvius ("C. Q." and "Iter") are also marked by thin lines, as is also the upper limit of the pons in the mesial plane ("Pons").

The upper boundary of the widest portion of the 3rd ventricle is marked by a thin broken line continuous with that of the "Iter." Its lower boundary corresponds with the line of the fissure of Sylvius. The extreme upper and lower boundaries of the 3rd ventricle in this drawing are the fornix above and the optic tract below.

9 and 9*a*. The fornix; marked by a thin crossed line. Its posterior pillars shown as continuous with the fimbria, &c., in the descending horn of the lateral ventricle. Its anterior pillars are also shown in part.

10. The lateral ventricle (a beaded line).
11. Grey matter of tænia hippocampi (in part). Thin broken line.

## Fig. III.

Right hemisphere, viewed from a direction 45° removed from the vertical.

Explanation of the lettering is the same as in the preceding.

The corpus callosum is shaded, for the sake of distinctness. The outline given shows its area in the middle line.

Only the terminal part of the optic tract is marked, so as not to complicate the drawing. The external geniculate body would come just below the optic thalamus from this point of view. The optic tract would coincide with the upper limits of the grey matter of the island of Reil.

8. The internal capsule dips down in the space between the lower edge of the caudate and the upper edge of the lenticular nucleus to reach the anterior end of the crusta, as shown in the drawing.

The position of the crura and pons is shown in two ways—1st, their area in the middle line; and 2nd, their maximum area from the point of view taken.

The former are marked in faint interrupted lines—"C.Q.," "Iter," "Base of crus, m.l." (mid line), "Pons, m.l." (*i.e.*, mid line), and "Base of Pons, m.l."

The latter are marked "crusta," "crusta," and "pons." The area occupied by the cerebellum is marked by a stronger interrupted line.

The fissures in all three drawings are, with the exception of those of Rolando and Sylvius, not named, because they are so clear.

In Figure III. the prolongation upwards of the fissure of Sylvius is not marked so darkly as its importance deserves, because it coincides with the line of the fimbria and fornix, and would obscure these structures if made darker.

These drawings are of interest in connection with the theory which localises sensation in the Rolandic area, because they show the different courses which the sensory and motor fibres must take in their passage to and from the cortex and internal capsule. There are two main differences:—

1. Since the sensory fibres are limited to the posterior part of the internal capsule, they will, in the major part of their course to the cortex, occupy a position posterior to and distinct from the motor ones, more especially if the sensory functions are mainly limited to the convolutions posterior to the fissure of Rolando.

   The occurrence of affections of sensation and of motion independently of each other is therefore possible if the lesion be subcortical.

2. Owing to the situation of the island of Reil and the lenticular nucleus, sensory fibres to the lowest portion of the Rolandic area must take a much higher course than would otherwise be the case.

On this account sensory fibres to the face and tongue may be involved in a deep lesion damaging the centre for the arm. This combination of anæsthesia and paralysis is sometimes observed clinically.

Drawings of this description will, I am sure, facilitate the localisation of lesions in the subcortical white substance of the brain, and thus prove of service clinically both to physicians and surgeons.

# THE DEVELOPMENT OF THE SKELETON OF THE LIMBS OF THE HORSE, WITH OBSERVATIONS ON POLYDACTYLY.

By J. C. Ewart, M.D., F.R.S., *Regius Professor of Natural History, University of Edinburgh.*

## Introductory.

From whatever point of view the limbs of the horse are considered, they are of surpassing interest. They afford a remarkable example of specialisation. Their development from primitive pentadactyloid limbs having to a large extent been established, they not only claim the attention of students of phylogeny, but they help in graphically illustrating the great principles which underlie the theory of natural selection. Further, from the horse ministering so greatly to our everyday wants, a knowledge of the structure and development of its limbs is without doubt of almost as much practical as scientific importance.

Notwithstanding the fact that, alike from a scientific and a practical standpoint, the limbs of the Horse have long demanded our careful consideration, there does not yet exist anything approaching a complete or accurate account of their development, and no attempt seems to have been made to contrast the stages through which they pass during their ontogeny with the limbs of the supposed ancestors of recent horses. Moreover, although numerous cases of polydactyly in the Horse have been described, only in a few instances has an intelligent attempt been made to distinguish between simple reduplication of the digits, and atavism or the restoration of lost digits.

Having recently had the opportunity of examining fœtal limbs at various stages of development, and of studying several specimens illustrating dichotomy and atavism, I now propose to state the results of my observations. In this paper I shall describe the development (as far as the material at my disposal admits) of the fore-limb, indicating as I proceed how the limb of the Horse at the various stages of its development agrees with

or differs from that of certain extinct forms (*e.g.*, Hyracotherium, Mesohippus, and Hipparion) to which recent horses appear to be genetically related.

## I. THE DEVELOPMENT OF THE SKELETON OF THE FORE-LIMB.

In works on the anatomy of the Horse very little is said as to the development of the bones of the limbs.

In Chauveau's large book on the *Anatomy of Domesticated Animals* (1), the references to development may be said to consist only of an enumeration of the centres of ossification for the respective bones. In the case of the large terminal phalanx (the os pedis), in some respects the most important and interesting bone in the limb, the statement is assuredly inaccurate. It is said to be "formed from a single nucleus of ossification." As I shall show later, the greater part of the large os pedis or "coffin" bone which supports the hoof is developed from membrane quite independently of the terminal phalanx, which is a cartilage bone.

In Veterinary works the trapezium (often styled pisiform) is said to be frequently present, but in the Works of Owen, Huxley, Gegenbaur, Flower, Macalister, and other Comparative Anatomists, the trapezium is either not mentioned or said to be absent.[1] Evidently there is some doubt as to the nature of the bone (often called pisiform in Veterinary works) found at times attached to the trapezoid of the adult horse.[2]

As far as I am aware, the smallest limbs hitherto examined were taken from an embryo which was probably considerably under 20 mm in length. In this embryo, which was studied by Rosenberg (2), the measurement from the inguinal fold to the point of the toe was only 2·3 mm. The smallest embryo I have obtained probably measured when fresh 20 mm., and the hind-limb from the inguinal fold 4 mm. In Rosenberg's embryo, which was probably over 10 mm., and under 15 mm., the ulna was represented by a strong nearly cylindrical cartilage. By its proximal end it almost embraced the radius, and at the lower third of its length, though considerably reduced in size, it was quite distinct and lying some distance apart from the radius. In Rosenberg's figure, through the lower third of the fore-arm the ulna is represented as about one-third smaller than the radius, and separated from the radius by a distance equal to its own diameter. In this embryo the metacarpals II and IV are described as approximately the same length as the middle metacarpal,

[1] In Huxley's *Vertebrated Animals* it is stated, "There are seven carpal bones, the trapezium being obsolete." Macalister (*Morphology of the Vertebrata*) says "carpus are seven, there being no trapezium" (p. 235).

[2] I am indebted to Emeritus Professor Struthers for first directing my attention to the occasional presence of a trapezium in the horse.

and not very much smaller. In the figure representing a section through the proximal half of the metacarpals the third has nearly twice the diameter of the second and fourth, and presumably the difference would be greater in the distal half. The metacarpals II and IV are, however, separated from metacarpal III by a distance equal to the diameter of the latter.

Apparently at this stage the ulna (when the size rather than the position is taken into account) bears very much the same relation to the radius as in Hyracotherium, while the metacarpals II and IV bear about the same relation to metacarpal III as they do in Hipparion.

This implies that even in an embryo about 15 mm. in length, the manus has already departed considerably further from the ancestral form than the fore-arm.

The smallest embryo I have examined, as already mentioned, probably measured when fresh 20 mm. The extreme length with the neck somewhat straightened was 23 mm. The various parts of the skeleton of the limb (fig. 1) consisted of cartilage. Unlike the limb already referred to, the radius (*r*, fig. 1) in the lower third of the arm is very much larger than the ulna (*u*), and the metacarpals II and IV are shorter and decidedly more slender than metacarpal III.

The humerus (*h*) is sigmoid in form, and considerably longer than the radius and carpals taken together. In the adult the humerus is nearly straight, and slightly shorter than the radius. In being curved, and longer than the radius plus the carpal bones, the humerus of the 20 mm. embryo agrees with that of Phenacodus.

The radius is relatively short and thick, being especially expanded at the distal end, but the expansion is inwards rather than outwards, the ulna being still left in full possession of the cuneiform (*c*). The ulna is complete, and nearly as large at its distal end as at its middle third. The upper end only slightly embraces the upper end of the radius, while its lower end, still circular in form, lies in a very shallow groove in the outer side of the radius. The middle third is separated from the radius by a considerable interval. At its lower end the radius is many times larger than the ulna, but at its middle third the diameter is only about one-half greater. As shown in

[1] For the embryos referred to I am indebted to Professor Mettam of the Royal Dick College.

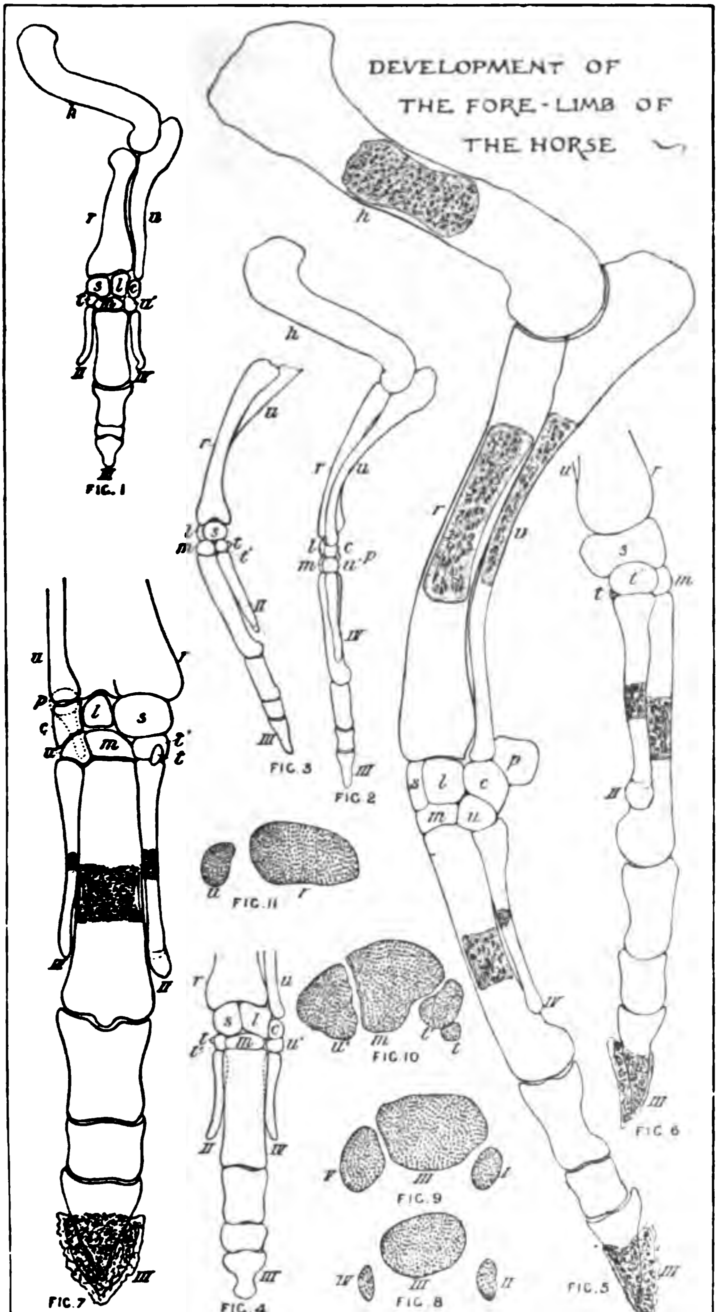

DEVELOPMENT OF
THE FORE-LIMB OF
THE HORSE
FIG. 1
FIG. 2
FIG. 3
FIG. 4
FIG. 5
FIG. 6
FIG. 7
FIG. 8
FIG. 9
FIG. 10
FIG. 11

figure 1, the ulna projects slightly beyond the distal end of the radius.

The carpal region differs from that of the adult in several respects. In the first place it is relatively longer.[1] In the horse[2] metacarpal III is five times and the radius seven and a-half times the length of the carpal region, but in the 20 mm. embryo metacarpal III is only twice and the radius only three and a half times the length of the carpal region.

In the next place the magnum is relatively narrower while the other carpals are relatively wider than in the adult, this being especially true of the trapezoid and unciform, which still lie in a line with, and only very slightly under cover of, the magnum. In the adult nearly one-third of the unciform and over two-thirds of the trapezoid lie behind the magnum. Already there is marked interlocking of the carpal bones,—the scaphoid extending as far over the magnum as in Hipparion.

Although in some respects presenting primitive characters, the carpal region more closely resembles that of the adult than might have been expected.[3]

As already mentioned, Rosenberg describes the metacarpals II and IV in a very young embryo as nearly as long and as stout as metacarpal III. As will be seen from figure 1, this is not the case in a 20 mm. embryo. Already the middle metacarpal is decidedly larger and distinctly longer than the outer metacarpals. These metacarpals are, however, still in a line with and not partly under cover (as in the adult) of the middle metacarpal at their upper ends, while they lie a considerable distance from the middle metacarpal at their lower ends.

Were the diverging metacarpals II and IV larger, the metacarpal region of this embryo would resemble that of the Rhinoceros more than any of the ancestral equidæ. I ought to mention that in fig. 1 the metacarpals II and IV look shorter than they actually were, owing to the curving at the lower ends.

[1] Figures 1 to 7 are eight times natural size; figures 8 to 11 are sixteen times natural size. All the figures were drawn with Zeiss' camera.

[2] The limb of a pony, from a skeleton in the University Anatomical Museum, was used for comparison—the pony was probably about 12 hands high.

[3] I failed to find a rudiment of a trapezium in my 20 mm. embryo, but this was perhaps due to the fact that the limbs were partly dissected before the trapezium was looked for.

In the case of the second the lower end was turned backwards as well as outwards; hence, though really longer than the fourth, it looks shorter in the figure.

As in the adult, the second metacarpal articulates with the magnum as well as with the trapezoid, while the fourth only articulates with the unciform.

In comparing the manus of this embryo with that of the adult, one is especially struck with the shortness and width of metacarpal III. In the adult the length of the third metacarpal may be five times its width at the widest part of its distal end: in this embryo the length of the third metacarpal is less than twice its width.

Not less remarkable than the size of metacarpal III is the great size of the first phalanx. It is relatively wide and more than half the length of metacarpal III: in the adult it is only about one-third the length of metacarpal III. The second phalanx is very short, while the terminal phalanx, though well proportioned, is altogether unlike the greatly expanded "coffin" bone of the adult. This difference, as will be shown later, is however not so much due to a difference in the terminal phalanges as to the presence in the adult of an accessory cap specially concerned in supporting the hoof.

From the description given, it will be evident that the manus in a 20 mm. embryo is not only quite unlike that of the adult horse, but also unlike that of any of the ancestral forms we are acquainted with. This is doubtless due to abbreviation in development, the abbreviation having in this, as in so many other cases, resulted in the formation of a manus which at this stage is quite unlike any of the phases through which the manus of the Horse passed during its evolution.

The manus of the Horse is more specialised than the arm and fore-arm. Probably owing to this fact, the abbreviation is far more marked in the metacarpal and phalangeal bones than in the humerus and the bones of the fore-arm.

The skeleton of the limb of a 20 mm. embryo evidently differs considerably from that of an embryo about 15 mm. in length—the distal end of the ulna is much smaller than the distal end of the radius, and the third metacarpal is not only much broader, but also somewhat longer. This seems to indicate that when

the embryo horse is about 20 mm. in length, the limbs are being hurried rapidly through the stages that in a modified way represent the conditions which obtained in the more remote ancestors; that, by as short routes as possible, the characteristic equine form is being assumed. Additional evidence of this is obtained if the skeleton of the fore-limb from a 25 mm. embryo (figs. 2, 3, and 4) is compared with that of the one of 20 mm. (fig. 1) described above. In the 25 mm. embryo the humerus and radius are better formed and more like the corresponding structures in the adult; the proximal end of the ulna is in more intimate relation with the radius, and the distal portion of its shaft is more slender. Further, the magnum is wider in front and more wedge-shaped when seen in section, while the trapezoid and unciform have retreated to some extent behind the magnum, and the upper ends of second and fourth metacarpals now lie partly behind the large middle metacarpal.

After a length of 25 mm. is reached further marked modifications seem to be for a time arrested. For example, although the limb skeleton in an embryo about 50 mm. in length is considerably larger than that of a 25 mm. embryo, and already in part ossified, the limbs as a whole as well as their several parts have essentially the same form and arrangement.

This being the case, I shall now proceed to describe the skeleton of the limb from a 25 mm. embryo, and thereafter the skeleton from a 50 mm. embryo. The skeleton of the limb of a 25 mm. embryo, like that of one of 20 mm., consists entirely of cartilage. The humerus in the 25 mm. embryo (which will be referred to henceforth as embryo B, while that of the 20 mm. embryo will be referred to as embryo A) is relatively shorter than in embryo A, though still relatively longer than in the adult. In being less curved and in having the upper end expanded, it may be said to more closely resemble the humerus of Hyracotherium than that of Phenacodus.[1] The radius is

[1] In making my comparisons I made use of (1) the cast of Phenacodus in the Edinburgh Museum of Science and Art, (2) the excellent drawings of Phenacodus and Hyracotherium by Cope in the *Report of the United States Geological Survey* (vol. iii. book i., 1884), (3) the equally valuable drawings of Mesohippus in the *Journal of Morphology* (vol. v., 1891) which accompanies Professor Scott's paper "On the Osteology of Mesohippus," and (4) the classical figures of Hipparion by Professor Gaudry.

nearly one-fourth longer than in embryo A; but though at both ends it approaches the form of the adult, it differs from the radius of the adult and agrees with that of Hyracotherium in being distinctly curved, and in having a groove on its outer expanded distal end for the ulna. The middle of the shaft is nearly oval in form (fig. 11, *r*), and somewhat smaller than the third metacarpal (fig. 9, III).

The ulna is at an extremely interesting stage. The upper end is well formed, and has nearly the same relation to the humerus and radius as in the adult. About the middle of its length it leaves the radius and assumes an oval form, which it retains until it approaches the greatly expanded distal end of the radius, where it becomes rounded as it passes the radius to reach and articulate with the cuneiform and pisiform. Fig. 11 represents sections through the ulna and radius a short distance above the expanded end of the latter. More distally the ulna lies in a wide groove on the outer surface of the radius. As it passes along the groove it assumes a nearly circular form, and eventually, when on a level with the upper part of the pisiform, comes into actual contact with the radius. At its distal end the ulna is nearly as large as the cuneiform (*u*, fig. 10). In studying the ulna in the 25 mm. embryo, I was even more struck with the marked curvature of its shaft (fig. 2, *u*) than with the completeness of its lower third or its distance from the radius (fig. 11).

The carpal region differed little from that of embryo A. It, however, more closely resembled the adult carpus in having the magnum more expanded in front (fig. 10, *m*), and as a consequence of this, overlapping to a considerable extent the trapezoid and to a less extent the unciform. Further, the carpal region was relatively shorter than in embryo A, though still relatively considerably longer than in the adult. In embryo B there was no difficulty in finding a trapezium. As shown in fig. 10 (*t*), it projected backwards and slightly inwards from the trapezoid, but as indicated in figure 4 it had no connection with the second metacarpal. In the adult the trapezium frequently articulates with both the trapezoid and the second metacarpal, while at times it articulates with the trapezoid only. In all probability, had the development been completed in the case under consideration the trapezium would have been found, as in the

embryo, articulating only with the trapezoid. In transverse sections the proximal carpals differed from those of the adult, being relatively longer from before backwards, and in the scaphoid and magnum being narrower in front. Though they indicate a considerable advance on Hyracotherium, they have not yet reached the amount of specialisation found in Mesohippus.

The metacarpal bones in B differ considerably from those of A. The third metacarpal is relatively longer; but though the length is equal to two and a half times the width, it is still relatively only half the length of the corresponding bone in the adult, and of the same relative size as the middle metacarpal of the Rhinoceros.

The metacarpals II and IV have about the same relative size as in embryo A, but they lie nearer metacarpal III at their lower ends and partly behind it at their upper ends. Figure 9 represents a section through the metacarpals immediately below the carpals. Figure 8, a section near the distal ends of the metacarpals II and IV. In both sections metacarpal II (V, fig. 9, II, fig. 8)[1] is larger than metacarpal IV. The second metacarpal had a small nodule of cartilage attached to its lower end. After maceration in a weak solution of alcohol this nodule was easily removed. It was of a perfectly definite form, and when mounted and examined with Zeiss' D, it was found to present a somewhat cup-shaped cavity, lined with a thin layer of connective tissue for the rounded lower end of II metacarpal. The presence of this nodule at the end of metacarpal II is extremely suggestive. It is well known that in the Horse the phalanges of the second digit are more frequently restored than those of the fourth digit. The restoration of the second digit is in fact so frequent that there is no escape from the conclusion that the second digit persisted longer than the fourth in the Horse family. It has even been suggested that "an ancestor of the horse may yet be found with the second and third toes alone developed" (3), and it appears that in Hipparion the second digit persisted longer than the fourth. It is of course impossible to say whether the nodule in the 25 mm. embryo represents the proximal

[1] In figure 8, the second, third, and fourth metacarpals are numbered II, III, and IV respectively; but in figure 9 the second metacarpal is numbered V and the fourth I.

phalanx or all three phalanges. It may, however, be mentioned that the reduction of the outer digits in the Horse seems to have been effected in much the same way as the outer toe of Man is now being reduced in size. Evidence of this I have found in three cases of reversion that have come under my notice. In fact, in no case have I found a complete and perfect restoration of the second digit. In one case the epiphysis of the second phalanx is all but united to the distal end of the proximal phalanx—it is, in fact, more intimately united to the proximal phalanx than to its own shaft. In one case, although the terminal phalanx and hoof were well formed, the second phalanx was represented by a pad of connective tissue, while the proximal phalanx was relatively short, and had its distal end rounded and reduced in size instead of expanded to form a wide articular surface. Taking these and other facts into consideration, I have come to the conclusion that the nodule found at the end of the second metacarpal is in all probability a vestige of the proximal phalanx only.

The first phalanx of the third digit, as in embryo A, is relatively long, being half as long as metacarpal III, whereas in the adult it may be only one-third the length of this bone. The second and third phalanges closely resemble the corresponding phalanges of embryo A.

The most noteworthy points about the skeleton of the fore-limb in a 25 mm. embryo are (1) the presence of a complete strongly-arched ulna, the middle third of which lies some distance from the radius; (2) the curved condition of the radius; (3) the presence of a distinct trapezium; (4) the shunting backwards of the metacarpals II and IV, so that they lie partly under cover of metacarpal III, while their related carpals lie partly behind the magnum; and (5) the presence of a nodule at the distal end of metacarpal II, which is probably a vestige of the lost proximal phalanx. While there is a resemblance between the humerus, radius, and ulna of embryo B and the corresponding structures in Mesohippus, there is a marked difference in the manus, even when only the middle digit is considered. For example, while the phalanges in embryo B are together longer than the third metacarpal, in Hipparion they are less than half the length of the third metacarpal.

I shall turn now to the 50 mm. embryo, which will be known as embryo C. As already indicated, the fore-limb of this embryo (fig. 5) chiefly differs from that of the 25 mm. embryo in having undergone partial ossification. When a careful comparison is made, however, it is found that there has been progress in all directions towards the conditions that obtain in the adult. The humerus is more like that of the adult in shape, and it is relatively shorter than in embryo B.

In the skeleton of the fore-limb of the pony the humerus is 4 c.m. (1½ inches) shorter than the radius; in embryo C the humerus and radius are of almost exactly the same length, thus differing from the smaller embryos, in which the humerus is longer than the radius plus the carpals.

It is interesting to note that in having the humerus and radius the same length, embryo C agrees with Mesohippus and shows an advance on Hyracotherium, in which the humerus is longer than the radius. A careful comparison of the fore-limb of embryo C with that of Mesohippus results in demonstrating that the humerus, radius and ulna of the one bear a striking resemblance to the corresponding structures in the other, the only real differences being that in Mesohippus the ulna is relatively somewhat stronger, while in the 50 mm. horse embryo the radius is more curved at the junction of its middle and lower thirds, and less intimately connected with the ulna.

Taking for granted that Mesohippus stands in the position of an ancestor to recent horses, it appears that when an embryo horse reaches a length of 50 mm. it, as far as the bones of the arm and fore-arm are concerned, reproduces the conditions which existed in the ancestors of the Horse that inhabited both the old and new world when the Lower Miocene rocks were in process of formation.

From figure 5 it will be observed that the humerus, radius and ulna are already partly ossified. In the case of the humerus and ulna the middle third has been ossified, while in the case of the radius the osseous matter extends nearer the proximal than the distal end.

The manus in embryo C, though decidedly more like that of the adult than in embryo A or B, really differs considerably when carefully examined. In the pony's limb the radius is

eight times and the third metacarpal over six times the length of the carpal region. In embryo C the radius is only six times and the third metacarpal only 3½ times longer than the carpal region. Hence, in this embryo, the carpal region is still relatively longer than in the adult, but it is relatively shorter than in embryo B; for while the manus plus the radius is two and a half times longer in embryo C than in embryo B, the carpus is only one and a half times longer.

It is somewhat remarkable that while the humerus, radius and ulna in embryo C closely resemble the corresponding structures in Mesohippus, the carpal region is far more specialized, *i.e.*, more like the carpal region of the adult horse. For example, in Mesohippus the carpal region is relatively longer than in embryo C. It is one-fifth the length of the radius, while in embryo C it is only one-sixth. This greater shortening of the carpus in embryo C than in Mesohippus is exactly what might be expected when the greater specialisation of the metacarpals and digits of the Horse is taken into consideration.

When the separate carpals are considered it is found that none of them have begun to ossify, and that the magnum covers over more of the trapezoid and unciform than in embryo B. Further, the trapezium no longer projects outwards, it now lies entirely behind the trapezoid, but, unlike the trapezium in embryo B, it articulates, as is very frequently the case in the adult, with metacarpal II as well as with the trapezoid.

The middle (III) metacarpal in embryo C is still quite unlike the middle metacarpal of all other forms. It is relatively shorter and broader than in the adult, but it has the same relation to the distal carpals.

The metacarpals II and IV occupy nearly the same position as in embryo B. The distal third or more of each projects slightly away from the middle metacarpal, instead of lying behind it as in the adult. The second, which is decidedly longer and thicker than the fourth, had a peculiar expansion at its lower end. This probably corresponded to the nodule found in embryo B, but owing to its intimate connection with the metacarpal proper it could not be readily detached.

In all these metacarpals ossification had set in, but in the

second metacarpal the ossification had proceeded further than in the fourth.

The united phalanges were relatively shorter than in embryo B, but still relatively longer than in the adult. In the adult they are about $\frac{3}{5}$ the length of the third metacarpal, in embryo B they are nearly the same length as this metacarpal.

All three phalanges were composed of cartilage. At first the terminal phalanx seemed to be partly ossified. It looked as if the ossification had started at the tip (as is the case in Man) and was gradually extending upwards.

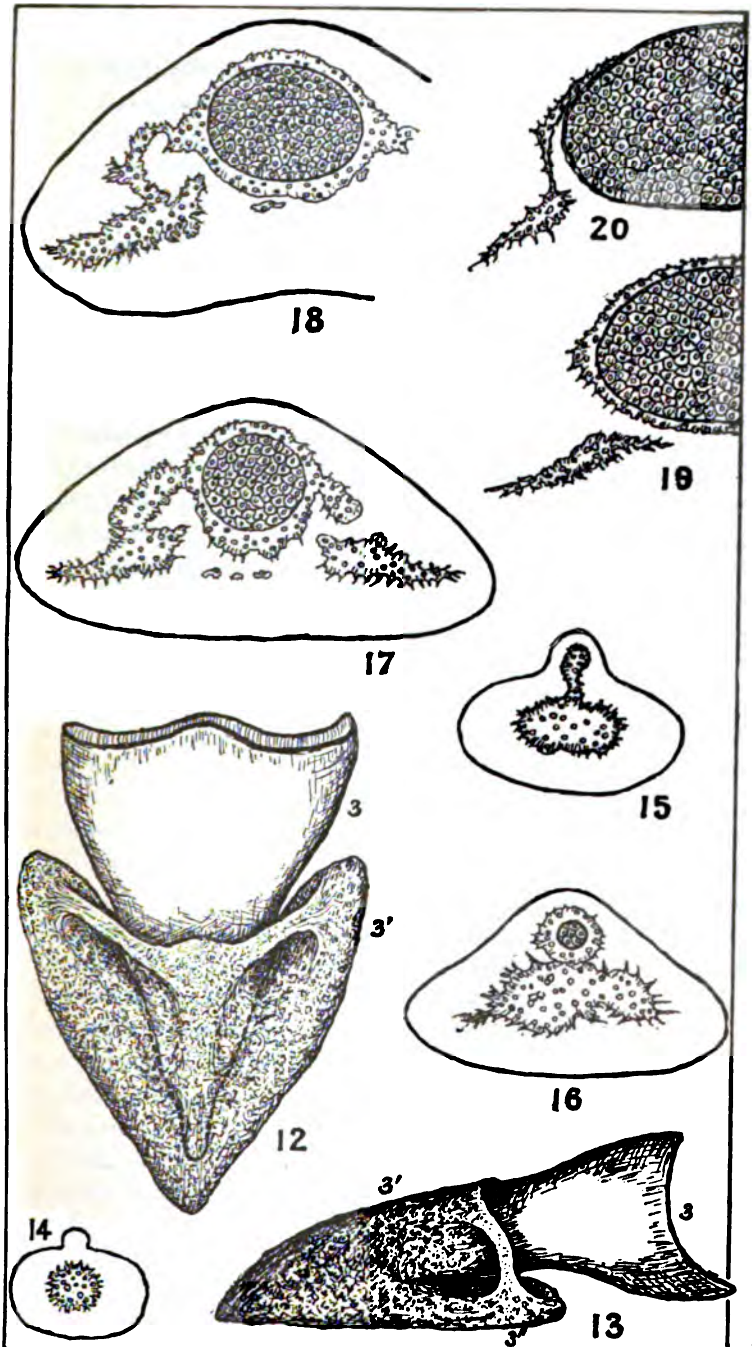
After a careful examination of the left terminal phalanx, and after studying longitudinal and transverse sections of the terminal portion of the left pes, it became sufficiently evident that the terminal phalanx had not yet begun to ossify, and that it was invested by a peculiarly-shaped bony cap, developed entirely from connective tissue.

At the outset I mentioned that the "coffin" bone is described as being formed from a single ossific centre. It always seemed to me unlikely that this large bone was developed from a single centre: it now turns out to be mainly composed of an accessory bony cap, developed quite independently of the terminal phalanx. The presence of a membrane bone around the terminal phalanx is exactly what might have been expected. In Man the expanded portion of the terminal phalanges which supports the nail is, as described by Dixey (4), developed from membrane; and even in Amphibians, as shown by Leydig (5), "the thickened tip of the terminal phalanx proceeds exclusively from ossified connective tissue."

A knowledge of the os pedis or "coffin" bone being, at least from a practical point of view, of considerable importance, I have made a special study of its development.

In embryo C the terminal phalanx is long and pointed (figs. 5, 6, 7, and 12), but, as in the first and second phalanges, there is no appearance of ossification, even in microscopic sections. The proximal part is shown in figures 5–7 and in figures 12 and 13 (3), and figure 20 represents a transverse section through the unaltered cartilage, on a level with the proximal part of the bony cap.

The cap presents a remarkable appearance in embryo C. It


18
20
19
17
15
3
3'
16
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14
3'
3
3'
13
J.C.EWART

consists (1) of a conical portion which invests the distal half of the terminal phalanx; (2) of an irregular terminal portion which lies beyond the point of the phalanx; and (3) of two wing-like expansions or lateral plates which project downwards and outwards, one at each side—each wing being connected to the cone investing the cartilage by an arch or buttress. An idea of the appearance of the bony cap will be gathered from figs. 12 to 20. Figures 12 and 13 represent the bony cap ($3^1$) fitted on to the still uninvested proximal part of the phalanx (3). Both figures show the flattened side-pieces, each connected near its free end to the bony sheath investing the phalanx. Figures 14 and 15 represent two sections in front of the tip of the phalanx.[1]

Near the centre of figure 14 there lies an irregular bony axis, and on the upper surface a well-marked ridge. In figure 15 the bony core is larger, and is connected with an osseous deposit in the dorsal ridge. Figure 16 represents a section through the tip of the cartilaginous phalanx, with its bony investment.

The tip of the phalanx lies in a line with the osseous deposit in the ridge seen in figure 15. It thus appears that the distal part of the bony cap is entirely independent of and on a somewhat lower level than the tip of the phalanx proper. The ridge with the bony axis in line with the apex of the phalanx, together with the anterior portion of the bony sheath of the phalanx, may be said to carry one back to remote ancestral forms, in which the pointed cartilaginous terminal phalanx was invested with bone for supporting a claw.

The wing-like expansions (figs. 17–20) doubtless correspond to the lateral portions of the expanded terminal phalanges of Man, and to the small lateral bony ridges in Amphibians.

In the Horse the lateral expansions have, however, reached a remarkable development. Each has grown downwards and outwards, and then expanded to form a large nearly flat plate (figs. 17 and 18). These plates, by growing inwards as well as outwards and backwards (figs. 12 and 13) to meet and blend with the thickened bony sheath of the phalanx and with each other, eventually form the greatly expanded lower portion of the os pedis.

[1] Figures 12 and 13 are 32 times natural size; figures 14–20, which represent sections through the pes of embryo C, are about 50 times enlarged.

From the first the upper surface of the bony cap presents a fenestrated or pitted appearance; hence in sections the lateral plate is sometimes found lying detached (fig. 17). But in the manus of the 50 mm. embryo not only are there fenestræ; but at each side near the base is a large gap, across which are at the most only a few delicate spicules. The position of this gap is indicated in figures 12 and 13, and figure 19 represents a transverse section through the gap immediately in front of the bridge (figs. 12 and 13), connecting the base of the conical part of the cap with the free end of the wing-like expansion.

Whether the gap exists from the first or results from the rapid backward growth of the wings I am unable to say, but it is completely filled up in somewhat older embryos (fig. 23). From the clean cut appearance of the edge of the buttress (fig. 12), the presumption is that the gap is simply a greatly enlarged fenestra.

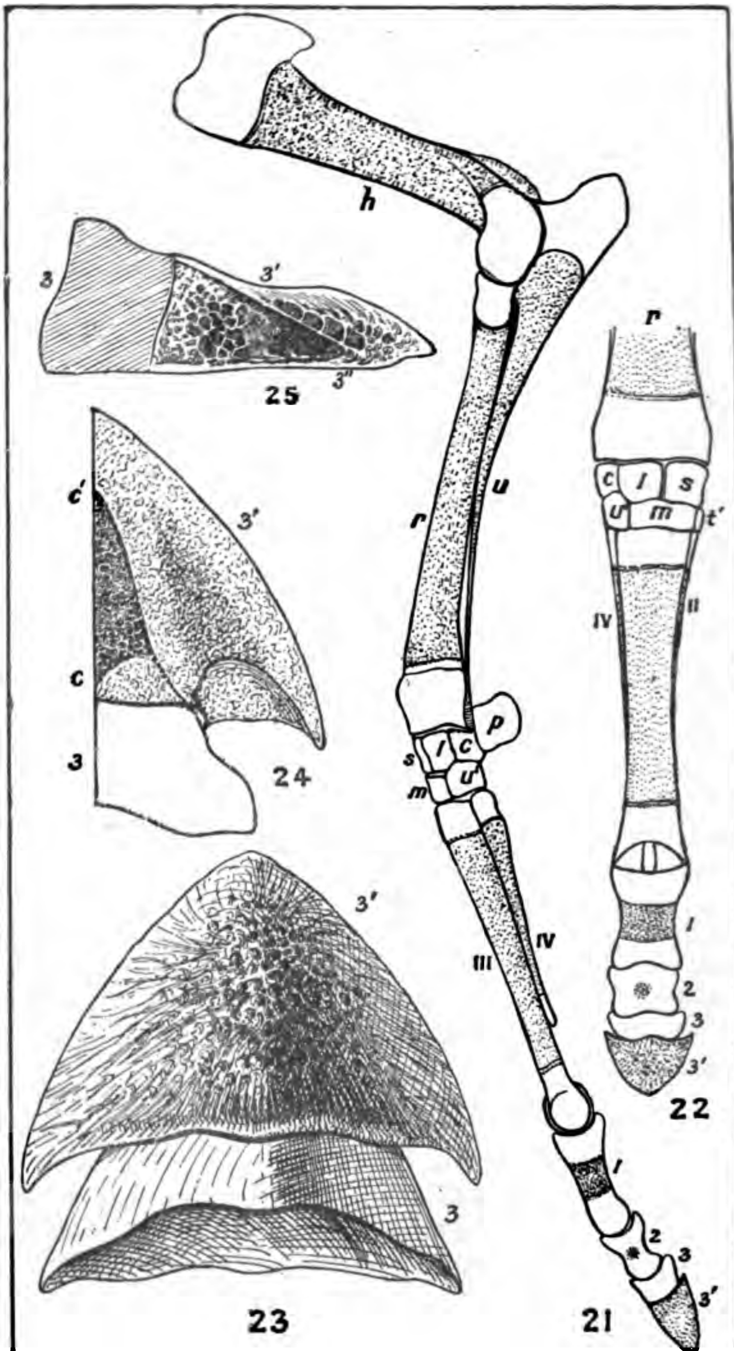
Figure 20 represents a section through the phalanx behind its bony investment, but through the proximal part of the buttress and the wing which it supports.

It will be observed that in figure 20, as in figures 15–19, the cartilage of the phalanx is quite unaltered.

To sum up, the fore-limb of a 50 mm. embryo is especially interesting, for the following reasons:—(1) the humerus, radius and ulna resemble closely the corresponding structures in Mesohippus; (2) the carpal region is shorter and in various ways more specialised than in Mesohippus,—it closely agrees with the carpal region in Hipparion; (3) ossification has set in, and has extended relatively as far in the ulna as in the radius, and further in the second than in the fourth metacarpal; and (4) although no osseous deposits have appeared in the phalanges, a remarkable bony cap has made its appearance around the distal portion of the third phalanx.

When referring to the ancestors of the Horse, Miohippus and Hipparion are usually mentioned after Mesohippus. In Mesohippus there is a splint-like vestige of the V metacarpal relatively as long as the fourth metacarpal in recent horses. In Miohippus the fifth metacarpal is present, but very short, while in Hipparion it appears to be seldom if ever present.[1] It has

[1] For a discussion on this question, the works of Gaudry may be consulted, also a paper by Hensel, *Abhandl. d. Akad. d. Wissensch. zu* Berlin, 1861.

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not been possible to make a comparative study between horse embryos and Miohippus, but this matters little, as the difference between the fore-limbs of Hipparion and Miohippus is not very great. As Hipparion is for many reasons more interesting than Miohippus, I consider myself fortunate in having been able to examine an embryo which stands in nearly the same relation to Hipparion as the 50 mm. embryo does to Mesohippus.

This embryo (which will be known as embryo D) was probably when fresh about 35 c.m. in length; from the end of the calcaneum to the tip of the toe the measurement was 13 c.m. Figure 21 represents the skeleton of the fore-limb of this embryo, natural size. Figures 1 to 7, which represent the fore-limbs of embryos A, B and C, are, as stated above, eight times natural size.

The fore-limb of the 35 c.m. embryo bears as a whole a striking resemblance to that of the adult horse; and when the various parts are considered, they will be found to agree more closely with those of the adult than in any of the embryos already described. The humerus is shorter than the radius—it equals the length of the shaft of the radius plus its proximal epiphysis. It is thus as nearly as possible of the same relative length as in Hipparion, and only a very little longer than in a small adult horse, in which the radius is about 4 c.m. longer than the humerus. Further, in embryo D the humerus is less curved than in Hipparion, and has nearly the same shape as in the adult horse, and both the shaft (which is well ossified) and the (still cartilaginous) extremities have all but assumed the adult characters.

The curving of the radius is almost identical with that in Hipparion, and not much greater than in some well-developed horses. The shaft is, however, relatively stouter and more rounded than in the adult, while the upper end is relatively less expanded and more completely embraced by the ulna. The ulna differs considerably from the ulna of the 50 mm. embryo, the olecranon process is more prominent and better moulded; but narrower from side to side. The upper part of the shaft is well ossified, and though relatively still large, it is narrower than in embryo C, and embraces less of the radius. As the ulna approaches the middle of the arm it rapidly tapers, and the lower third is represented by a tube of connective tissue (the

somewhat altered perichondrium), containing a few cartilage cells. The greatly reduced ulna lies slightly apart from the lower third of the shaft of the radius, but later it comes into contact with the cartilaginous epiphysis and then expands slightly before reaching the ulna. Apparently in some cases the whole of the lower third of the ulna is absent in the adult, but in others, more especially in small horses, the ulna may be complete with the exception of a break of from 3–4 c.m. opposite the upper end of the lower third of the radius. When the distal end of the ulna persists in the adult, it is in all probability developed from the connective tissue that originally surrounded the distal portion of the cartilaginous ulna, and that still persists (fig. 21) in embryo D. Although the upper end of the ulna is relatively as well developed in embryo D as in Hipparion, the lower end, judging from the figures I have been able to study, is undoubtedly more slender. On the other hand, it appears to be more independent of the radius.

The carpal region, compared with embryo C and with Hipparion, is relatively shorter, and hence more like that of the adult. In C the radius was six times longer than the carpus; in D it is six and a half times longer, and thus approaches nearer than in the adult, in which the radius may be eight times longer than the carpus. In Mesohippus the radius is five times and in Hipparion five and a half times longer than the carpus. The magnum is relatively nearly as wide as in the adult, and the trapezoid and unciform have nearly the same relation to the magnum as in the adult. As in embryo C, there was a trapezium lying behind the trapezoid, and articulating with the II metacarpal as well as with the trapezoid. Even in this large embryo the carpal bones had not begun to ossify.

The third metacarpal bone in embryo D is relatively as long as in a small horse; but its shaft is relatively considerably wider, while the proximal and distal ends are slightly narrower. The metacarpals II and IV are nearly as completely hidden by metacarpal III (fig. 22) as is the case in the adult. All three metacarpals had their shafts well ossified, and the second was decidedly longer than the fourth, and, as in embryo C, the distal end was somewhat expanded.

The three phalanges in embryo D are of the same relative length as in the adult, but, as was the case with the III meta-

carpal, they are relatively wider. The proximal phalanx was partly ossified, and there was a small ossific nucleus in the second phalanx (figs. 21 and 22). The third phalanx appeared at first as if it were still entirely cartilaginous, but on making a longitudinal section, it was found that the terminal half had begun to ossify within the bony cap.

The extent of the ossification of the terminal phalanx will be seen by referring to figures 24 and 25. Figure 25 represents a longitudinal section through the phalanx and its bony cap. In figure 24, which represents a view from below, the extent of the ossification (*c.c'*) of the phalanx is indicated as seen through the bony cap after clearing with cedar-wood oil. Compared with embryo C, the terminal phalanx is now much shorter and less pointed, and the basal portion, though still cartilaginous, closely resembles the most proximal part of the adult os pedis. In front, immediately above the articular surface for the second phalanx, it presents an elevated ridge for the attachment of the tendon of the flexor pedis, and behind, some distance below the articular surface, a slight ridge for the deep flexor of the phalanges. As in the adult, the articular surface at each side projects outwards and upwards. It may be here mentioned, that even in old horses the proximal part of the os pedis, developed by the deposition of osseous matter in the phalanx proper, can easily be distinguished from the accessory bony cap developed in connective tissue. This is due to the fact that the further encroachment of the cap is eventually arrested by the ligaments and tendons which lie in contact with the synovial membrane, and form a sort of capsular ligament around the joint, between the second and third phalanges.

In the case of the 35 c.m. embryo, the bony cap has invested more than half of the phalanx. Owing to its great width, and to its being more transparent than the phalanx, its form is easily made out—the tips of the wings being especially evident (figs. 23 and 24).

The cap in D differs greatly from that of embryo C. In D it resembles more closely the arrangement in the adult. There are no longer larger gaps on the upper surface, and the wing-like lateral plates have so completely blended with the conical sheath investing the phalanx that only apertures are left for the great vessels of the os pedis. When examined with a lens, the cap is

seen to be extremely porous, more especially on its upper or dorsal surface. In a longitudinal section (fig. 25) it is found to extend some distance beyond the tip of the phalanx, and to be much thicker above than below the phalanx. It is especially thick above the terminal part of the phalanx, where it forms a distinct prominence (fig. 25.) In the vicinity of the prominence the pores are especially evident, and in the section they are seen to lead into comparatively large sinuses which lie around the apex of the phalanx.

In stained sections through the pes of the same embryo, the difference between the bone of the investing cap and the new bone forming in the cartilage of the phalanx is at once evident.[1]

In older embryos, it remains to be seen whether the proximal part of the third phalanx is ossified from a separate centre, as in Man, and whether the lateral processes are developed in connection with the phalanx or with its accessory cap.

The 35 c.m. embryo may be said to be mainly interesting for the following reasons:—(1) the humerus, as a whole, closely resembles that of Hipparion, and only differs slightly from that of the adult horse; (2) the radius agrees with that of Hipparion, while the ulna, which is now extremely slender at its lower third, is undoubtedly more reduced than in Hipparion; (3) the carpal region is shorter than in Hipparion, and though still longer than in the adult horse, it presents as nearly as possible the same arrangement of its various elements; (4) the trapezium is present, and occupies the same position as in embryo C; (5) all the bones are in process of ossification with the exception of the carpals; the ossification having gone considerably further in both the humerus and radius than in embryo C, while it has been arrested in the middle third of the ulna; (6) the distal half of the terminal phalanx is in process of ossification, and the investing cap, which is now of considerable size, resembles in form and texture the outer portion of the os pedis of the adult.

In my next communication I hope to complete the account of the development of the fore-limb, and, after referring shortly to the development of the hind limb, to describe several specimens illustrating polydactyly in the Horse.

[1] These sections will be figured and described in the second part of the paper.

(*To be continued.*)

# THE DEVELOPMENT AND VARIETIES OF THE SECOND CERVICAL VERTEBRA. By Professor A. MACALISTER, F.R.S. (PLATES IX., X.)

## I. DEVELOPMENT.

IN the history of the growth of the axis, as in that of any of the other vertebræ, two successive processes of growth are to be observed, that of chondrification and that of ossification.

The former begins at the end of the second week; first, by the formation of cartilage in certain parts of the *membrana reuniens* on each side of the neural canal; and secondly, in the perichordal sheath.

The first centres of chondrification appear as two lateral masses, one on either side of the neural cord. These extend backwards in the *membrana reuniens*, and ultimately unite with each other posteriorly, so as to form a cartilaginous neural arch.

The ventral ends of the lateral masses become also united together by the formation of a hypochordal bridge of cartilage (the "spange" of Froriep). In this way a gristly ring is formed which incloses the notochord and its sheath as well as the embryonic spinal marrow.

I have not succeeded to my satisfaction in tracing the successive stages of this process in the human embryo. It is not hard to follow them in the sheep embryo, or in the ox, as Professor Froriep has done. As far I can see, the hypochordal bridge of the axis is smaller than that of the atlas, but larger than that of the 3rd vertebra in the human embryo.

External to the point at which this lateral mass narrows into the hypochordal bridge, there arises from it a lateral cartilaginous outgrowth on each side, which projects into the embryonic tissue of the inter-muscular system between the muscle plates. The longitudinal anastomotic vessel which connects the several inter-protovertebral arteries, and which becomes the vertebral artery of the adult, passes along the lateral face of this out-

growth, dividing its extremity into dorsal and ventral portions. In the axis the former is the larger, the latter being very small and at first with difficulty recognisable.

As the indefinite blunt point in which each of these terminates grows outwards, it engirdles the artery by joining with its neighbour so as to complete the cartilaginous boundary of the arterial canal.

While the formation of this vertebral ring is in progress, a small centre of chondrification appears on each side, in the embryonic tissue sheathing the notochord. These appear on the caudal side of the hypochordal bridge, and by uniting around the notochord they form the cartilaginous body of the second cervical vertebra, and ultimately this coalesces with the hypochordal bridge.

A similar perichordal body has likewise originated in the atlantic segment, but it remains discontinuous from the large hypochordal bridge of the atlas, as the intervening embryonic tissue becomes partly fibrous while a considerable portion of it disappears, especially in front and behind, thus forming articular clefts on the dorsal and ventral surfaces of this somewhat conical body-element.

The base of this perichordal body of the atlas becomes united on each side by a continuous chondrification, with the hypochordal bridge of the axis at the region at which that bridge is attached to the lateral mass of that gristly vertebra. Medially the body of the atlas becomes attached to the cephalic surface of the perichordal body of the axis, by a layer of embryonic tissue which speedily becomes hyaline cartilage.

These processes have taken place by the end of the sixth week, at which period the cartilaginous vertebra, as yet showing no sign of ossification, presents the following parts,—a complete neural arch, having at each side of its base a thick lateral mass from which transverse and costal processes jut outwards. The body, which is medio-ventral, is formed by the union of three elements—the hypochordal bridge of the axis, the perichordal body of the axis, and the perichordal body of the atlas—the last named forming the cartilaginous *dens*.

The first signs of ossification appear late in the seventh week. In several sixth-week embryos there was no sign of any bony

depositions; but in all that I have seen over eight weeks, ossification has well begun.

The history of its bony development may be divided into the following 11 stages:—

1. *Development of the neural arch.*—The first bony granules appear in the lateral mass during the seventh week, and, from these points, ossification extends into the neural arch. In an 11th-week fœtus there is in each half of the arch a slightly-curved, club-shaped rod 2 mm. long (fig. 1), slightly flattened at its hinder end.

In a 12th-week fœtus these rods are thicker and longer than are the corresponding parts of any other vertebra. Their anterior extremities appear bilobed, an outward spur projecting into the lateral process, and an inner projecting towards the body.

In two bones of the 16th-week the hinder ends of the neural rods have become distinctly thickened and flattened. The fore ends are more strongly incurved towards the body, and the inferior articular processes are partially ossified, forming distinct joints with the third vertebra; ossification has extended to some extent into the short transverse process.

2. *Development of the body.*—In the 16th week bony growth has begun in the body of the axis, in the form of two contiguous nodules. In a 17th-week axis, these have coalesced to form a bilobed body nucleus.

3. *Ossification of the dens.*—In the 19th week, in one specimen, two unequal centres of ossification appear in the cartilage of the dens near its base, above the body nucleus, which is rapidly growing. In this case the right nucleus is large and rounded, the left small and irregular. In another of somewhat later age, the left centre is large and the right is a rudimental speck. In another, at the 22nd week, the dens-nuclei are equal, rounded, and symmetrical. In a 6th-month fœtus these are asymmetrical rounded nodules, the left larger than the right, and together they make a bony mass 3·5 mm. wide and 1·7 mm. high, placed on a bony axis-body, which is 3·25 mm. wide and 2 mm. high, and faintly bilobed below, with a central dimple corresponding to the place of the vanished notochord. The arch in this vertebra contains a curved bony rod on each side, 9 mm. long, and it is slightly grooved on its cephalic surface for the second cervical nerve. The vertebra in this stage is about 17 mm. in sagittal diameter, and about 10 mm. in coronal. Its arch is gristly in front and behind as well as at its lateral process.

4. *Coalescence of the nuclei in the dens* takes place usually during the latter half of the sixth month. The resulting bilobed mass is faintly grooved along the anterior line of junction, deeply grooved along the posterior line, and wider than the subjacent body (averaging 4 mm. by 2·5, while the body averages 3·5 by 3). There are some varieties in the time of this fusion. In a 7th-month axis I have found the dens nucleus as a rounded mass, while in the axis of a child of five months old the two dens-centres were separate as large oblong bony masses placed side by side (fig. 5). This condition is very exceptional.

The part of the arch which abuts on the body in these specimens is nodular, showing that ossification is here in active progress. Above this end is a plate of cartilage continuous with the lateral angle of the dens. This, in a macerated axis at this stage, becomes easily detached from the underlying end of the neural arch, and appears as a lateral flap at each side of the dens. The upper surface of this plate articulates with the under side of the lateral mass of the atlas, the articular cleft between them being visible at the fifth month, probably much earlier.

Although I cannot find any other structural differentiation between these cartilages and the underlying end of the lateral mass of the axis, it is yet probable that this layer is genetically connected with the dens rather than with the arch cartilage. I am satisfied that Froriep is right in describing the articular slit of the inferior atlanto-axial joint of the ox as being between the lateral mass-cartilage of the atlas and the expanded base of the dens, so that the joint is intra-atlantic not atlanto-axial. The lateral parts are more flattened and the dens is more columnar in Man than in the quadruped, but their relation seems to be the same. A considerable portion of this cartilage, both in Man and Ox, is ossified from the arch centre.

In 7th-month fœtuses the dens has grown larger than the body beneath it, the former averaging 5 mm. by 3·5, the latter 4 by 3. There is still a groove on its hinder surface, and medial notches filled with cartilage above and below. The widest part of the dens-nucleus is at the front of the base; from this it narrows to its notched apex. The widest part of the body-centre is behind and below. The arterial foramen at this time is bounded by bone behind as well as internally.

At birth the bony dens averages 9 mm. broad by 7 high. Its rounded and expanded base abuts on the upper half of the inner face of the arch, the body occupying the lower half. There is no ossification in the apical cartilage. The spinal end of the lamina is dilated, its outer angle swollen, laying the foundation of the bituberculate spine. The costal process is cartilaginous, except in one specimen, in which it contains a minute bony granule. Otherwise both it and the transverse process ossify as outward extensions from the arch-centre.

5. *Consolidation of the body of the axis with the arch* takes place during the second year, beginning usually at the hinder side. In my specimens from children over three years of age, this union is complete.

6. *Closure of the neural arch* by the median union of the laminæ takes place in general before the end of the third year. In one of my specimens it has been completed at twenty-eight months, while in another it has just began at forty-five months. The hinder aspect of the immature neural arch shows a lateral tubercle at each end of a median flattened area. By the end of the tenth year these tubercles have extended downwards on each side as the lateral tubercles of the spinous process, and they bound between them a triangular notch. I have found no trace of a terminal spinous epiphysis comparable with that of the thoracic or lumbar vertebra, but, as will be hereafter noted, there is sometimes an ossicle on the under side of each lateral tubercle

which may become consolidated as a depending cornu, and may represent the spinous centre.

7. *Union of the lateral margin of the dens with the arch of the axis*, in my specimens, begins posteriorly in the 3rd year, and is completed in my specimens of 4½ years.

8. *Ossification of the wedge-shaped cartilage* which occupies the summit of the dens, takes place in general by an extension of bony growth from the underlying centre, but sometimes an apical nucleus forms in the front and upper part of the cartilage. Sir G. Humphry figures a specimen of this from the Berlin Museum, and describes another from the Museum at Prag. In Cambridge we have six examples, one from a child aged 45 months, in which the arch has not completely fused with the dens and body on the left side. This nucleus is very small, and in the centre of the cartilage. In a second of 4 years, the centre is larger; a third, at 5 years, has a wedge-shaped ossicle at the bottom of the apical notch; a fourth, from an ancient Egyptian child, has a large rounded nodule of bone here. In the fifth, the nucleus is ankylosed to the dens, but its margin is still distinct; and in the sixth it is apical, as in Sir G. Humphry's figure (*Human Skeleton*, pl. vii. fig. 4). This is doubtless the homologue of an apical epiphysial nodule, such as that which I have figured in *Balænoptera rostrata* (*Phil. Trans.*, 1868, pl. vi. fig. 2). In all these the region of the dens from which the occipito-axial ligaments spring, is ossified by extension from below, not from this centre.

9. *Closure of the arterial canal* takes place at a variable period, and in a variable manner. In one of 4 years old it is closed; in one of 10 years it is yet open; while in some it never closes. Most commonly, however, it closes at about 5 years of age, by the extension of ossification forwards around the artery from the hinder crus. In one or two, ossification seems to have proceeded at nearly equal rates in the fore and hind crura, while in one the anterior crus has ossified more rapidly than the hinder. It thus sometimes happens that the terminal tubercle is sometimes ossified from the posterior, sometimes from the anterior crus.

I have found no specimen with a terminal epiphysis on the transverse process, such as I have described on the atlas. In one example only was there an independent bony granule in the pre-arterial crus.

10. In five specimens, two from children a little over 1 year old, one from a child aged 3, one from a child of 4, and one from an ancient Egyptian child, probably about 5, there is an additional nucleus present on each side at the under part of the base of the pedicle in front, just where it abuts on the body of the axis, and underlying the overlapping base of the dens. This extends to the inferior surface of the pedicle, but does not extend backwards as far as the arterial foramen, from which it is separated by the inner end of the pedicle (figs. 7 and 8).

The tissue in which this centre forms corresponds to the part of the cartilaginous axis which is derived from the lateral angle of the hypochordal bridge, and therefore this centre is strictly homologous in

position with that in the anterior arch of the atlas. This relationship was foreseen by Sir G. M. Humphry long before the researches of Froriep had shown that there was a hypochordal element in the axis (*Human Skel.*, p. 130). It is noteworthy that although I have only found this element in four out of thirty-one axes (about 13 per cent.), yet in others in which it was not present, there is along the upper and lower surface of the ossifying inner end of the pedicle a row of dimples in the end of the bone along the line at which this nucleus, if present, would have abutted on the arch. This centre has, obviously, nothing costal in its nature.

11. *The dens begins to ankylose with the body of the axis* early in the third year by the formation of superficial bands of ossification from one to the other, both behind and in front. By the beginning of the sixth year superficial union is complete in front, and the posterior interval is reduced to a large hole. An irregularly lenticular cartilage persists through life intermediately, as Sir G. Humphry has described. In a child of 10 years this was a considerable plate, limited superficially by a thin skin of bone in front and behind. In an old man of 85 years there was still a speck of cartilage persisting. This is true hyaline cartilage, not analogous to the tissue of the nucleus pulposus. A few bony specks in an irregular line along the lower border of the body represent the inferior epiphysial plate of the axis. This I have seen in an axis at 16 years. They consolidate rapidly, for I have found it fully consolidated at 20.

I have carefully examined the surfaces of the intercalated disk of cartilage between the body and dens, and in three specimens at about 16 or 17 years of age I have found a few bony granules, both at its upper and lower surfaces. These probably represent the epiphysial plates of the contiguous surfaces of atlas and axis, like the laminæ in this region which I have figured in Balænoptera. In no case did these form a definite epiphysial lamella, and they seem to have become completely consolidated with the neighbouring bone by 20 years of age.

It will be noted that my specimens in many respects differ from those from which M. Robin has given his account of the development of the axis, in his *Memoire sur l'evolution de la Notocorde, &c.* (Paris, 1868, p. 95). He had only found single centres in the body and dens, and no apical epiphysis. This is probably due to his specimens not representing the earliest stages.

## II. Varieties of the Axis.

Most of the deviations from the common conditions of this bone are in matters of detail, unimportant and easily overlooked. Those which are illustrated by my specimens are as follows :—

A. *Varieties of the Spinous process.*—In the normal axis the spine presents (1) a median superior ridge to which is attached a weak fibrous lamella attached to the ligamentum nuchæ, but consisting chiefly of condensed areolar tissue. To each side of this ridge is attached the origin of the rectus capitus posticus major. On each side is (2) the lateral oblique surface of the spinous process, more or less hollowed and ridged for the origin of the obliquus capitis inferior. At the posterior extremity of the ridge and surface is (3) the posterior surface, often only linear and continuous downwards from the median ridge, prolonged at its inferior angles into (4) the lateral tubercles into which the semispinalis colli is inserted. Between the lateral tubercles is (5) the posterior median notch; and in front of each tubercle at the inferior border of each lateral surface there is generally an inferior tubercle into which, and into the rough surface below and internal to it, is inserted the multifidus spinæ. The relative proportions of all these parts show many varieties. My statistics are taken from 150 bones.

1. The length of the spine is variable: my longest (fig. 11) measures 23 mm.; my shortest (fig. 12) 14 mm.

2. The superior ridge is obsolete in 2 per cent. This is the retention of an immature condition. In a considerable number this edge is sharp, sometimes up-raised above the level of the laminæ. In four specimens there were small friction facets for the under edge of the hinder tubercle of the atlas, on which there were similar facets, a variety omitted in my last paper. This facet in one is at the front, in two near the middle, and in one at the side of this ridge (fig. 15, *f*).

3. The inter-tubercular width is very great, measuring 28 mm. in a Saxon axis, from a secondary interment in Bowl's barrow (fig. 13). This is also a character of immaturity. The narrowest notch is in an Egyptian axis, measuring 7 mm. In this the spine is reduced to a median ridge with closely approximated posterior tubercles. In one the median ridge and the right lateral tubercle have terminally coalesced into one point (fig. 14).

4. The lengths of the lateral tubercles may vary; in general they project little below the level of the lower edge of the lamina, but in three they are long and prominent, becoming in one 18 mm. long (fig. 16). In one they were represented by detached ossicles, as in the instance described by Luschka (*Anatomie*, i, p. 39). In one of mine the right is long and the left short, showing a facet to which probably such an ossicle was attached. In another these tubercles are markedly asymmetrical, the right being lower and displaced to the left underlying the left tubercle. Another has a facet at each end of the posterior surface, to which probably ossicles were attached, but they have been lost. The degree of eversion of these tubercles also varies: in one their points are turned horizontally outwards.

5. In one specimen the posterior surface is a flat triangle, instead of being linear as it is usually.

6. The inferior median ridge, to which a thin elastic inter-spinous lamella is attached, is very sharp and prominent in one, obsolete in another, moderate in the rest.

B. *The lateral process* is normally peculiar in that it is never truly

bituberculate. Its single tubercle represents the posterior or true transverse process-tubercle of the lower cervical vertebræ, and gives attachment to the scalenus medius, levator anguli scapulæ, and splenius colli. The anterior or costal tubercle is represented by an obsolete or rudimental prominence in front of the superior articular process, at the outer end of the variable infra-articular ridge. To this point the rudimental intercostal muscle (anterior inter-transverse) is attached. This ridge and tubercle, when present, should therefore be called the *costal ridge*. The continuation of this to the tip of the transverse process is in series with the costo-transverse lamella of the other vertebræ, and it is occasionally channelled internal to its apex for the anterior branch of the second cervical nerve.

The bone may present other grooves for nerves, the chief one being the supra-pedicular groove behind the articular process for the ganglion and trunk of the second nerve. This area is always swollen and often has a definite border. There also may be one on the inferior surface of the transverse process, when that is longer than usual, for the anterior branch of the third cervical nerve. This is rare; I have only two distinct examples. A more common groove is the ascending sulcus between the posterior crus of the lateral process (fig. 17, *i*) and the front margin of the inferior articular facet, for the posterior branch of the third cervical nerve.

The extremity of the transverse process is short and tuberculate in 70 per cent.; longer and with a superior neural groove in 2 per cent.; subulate and decurrent in 15 per cent.; directed strongly backwards and downwards in 5 per cent.; very short and blunt in 5 per cent.; and dilated at the end in 3 per cent.

A line joining the tips of the opposite transverse processes lies behind the plane of the dens, but cuts off the hinder part of the superior articular surfaces in 60 per cent. It cuts both articular surface and dens in 36 per cent.; it is tangential to the articular process and behind the dens in 3 per cent., and lies quite behind both in 1 per cent. In most of my specimens the angle formed by the decurrent costo-transverse process with the vertical axis is about 50°.

When viewed from above, the lumen of the arterial foramen is not visible in 93 per cent.; in 2 per cent. it is visible on both sides; in 5 per cent. it is slightly visible on one side or on both. The *cryptotrematic* or ordinary condition is usually associated with a greater curve in the artery than is found in the *phænotrematic* condition.

In two specimens the lateral processes are almost completely hidden under the superior articular surfaces: in one (fig. 20) the extreme inter-articular width is 43 mm., and the extreme inter-transverse 45 mm. On the other hand, when the transverse processes are more horizontally placed, and do not project so much backwards, they are more prominently exserted. In one such specimen the inter-articular width is 47 mm., while the inter-transverse is 63 mm. (fig. 19).

The sides of the notch, between the back of the transverse process (fig. 18, *j*) and the front of the inferior articular process (*k*), usually form an angle of 90°, but in about 4 per cent. this is reduced, in one being only 40°. This reduction is due to the greater displacement backwards of the tip of the transverse process (*cf.* fig. 17).

The posterior crus, or real base of the transverse process, is deficient in four specimens. It is completely absent in two (fig. 21), represented by a faint spur in one, by a longer spur in another. This element is very slender in 3 per cent. This deficiency is described by Henle (i. 52). I have never seen the anterior crus deficient in an adult bone, although it is the later part to ossify in the immature lateral process.

C. The upper articular processes are separated from the dens by a sulcus (fig. 19, *l*) in nearly every case, and there is a vascular foramen in this in about 60 per cent. Each of these articular surfaces is slightly concave coronally, but convex sagittally. The tangent line joining the front border of these facets touches the body at the root of the dens in 23 per cent., lies in front of the body in 43 per cent., and cuts the front of the body in 34 per cent.

The shape and curvature of the upper articular processes are similarly constant, as the condition of this joint are subject to such slight variety, it being in all normal cases a laotrope screw joint, as Henke long ago recognised.

D. The cordiform spinal canal has an average width of 22·5 mm., the range being from 20 mm. (10 per cent.) to 27 mm. (1 per cent.). The sagittal depth on the lower surface averages 15 mm., but ranges from 12 (2 per cent.) to 20 mm. (4 per cent.). The average index, $\frac{\text{sag.} \times 100}{\text{cor.}}$ is 70, the range being from 60 (4 per cent.) to 85 (1 per cent.).

E. Seen from below, the arterial foramen presents certain variations of form, which are reducible to two types. In 80 per cent. the opening is a round hole with a definite margin all round (fig. 17, *g*). In 20 per cent. the opening is an elliptic fossa, with a rounded and distinct anterior margin, but the wall of the fossa posteriorly is undivided for the rest of the under side of the pedicle. In most of these cases the posterior crus is

small (fig. 18), and its edge does not extend inwards as a distinct ridge on the pedicle. In these cases there is usually the mark of a very spiral vertebral artery. In one such specimen the artery has deeply indented the side of the vertebral body. In the specimen figured, it touches the side of the body at *m*, but does not indent it (fig. 18). Varieties of size of the foramen are not uncommon. It is very frequently asymmetrical, and in one case is reduced to a fine hole on the right side. This foramen is never double or divided.

F. The front of the body varies chiefly in the degree of prominence of the triangular ligamentous area, in the sharpness of the inferior lateral tubercle, into which, and the ridge above it, there is inserted a strong ascending cervical stellate ligament figured by Luschka (*Anat.*, i. p. 46). This is crossed obliquely by the intercostal muscle ascending from the costal process of the 3rd vertebra (ant. inter-transverse), which ascends obliquely inwards to the lower border of the costal ridge.

The muscular depression on each side of the triangular area is for the accommodation of the longus atlantis muscle. Its depth depends on the forward projection of the costal ridge and the articular process above it.

G. The dens displays few striking varieties. In No. 1558 (*Path. Mus. Camb.*) it has become detached as the result of disease. Cases of detached odontoid without disease have been described by Giacomini and by Romiti, and other instances which were probably pathological are described by Shaw (*Trans. Path. Soc. Lond.*, ix. p. 346) and Turner (*Jour. Anat.*, xxiv. p. 258, 1890). The firmness of the dens, which is so distinctly shown by vertical sections, has been proved by the experiments of Dr Stephen Smith, who demonstrated that the dens was capable of resisting a force sufficient to break the anterior arch of the atlas or the transverse ligament (*Amer. Jour.*, iv., N.S., p. 338).

The average height of dens to height of body is as 17 mm. to 20 mm. in males, as 15 mm. to 19 mm. in females, but the dens may be only 12 mm. or may be 19 mm. high. It is usually short and subulate in such Australians as I have seen (6). The principal varieties are in the shapes and extent of the anterior or atlantic facet, and the relation of the plane of this surface to the vertical axes of the bone. In old bones there is often an

*occipital process* at the top of the dens, which extends behind the anterior atlanto-occipital ligament to touch the basi-occipital. In one specimen this is twofold, an anterior lamellar process, and an apical tubercular process, the ossification of the tissue around the suspensory ligament. In one instance of atlanto-occipital ankylosis the dens articulated with two lateral bony processes from the occipital bone, which replaced the check ligaments. The various shapes of the dens may be described as clavate, cylindrical, subulate, or else some form intermediate between these extremes.

H. The inferior articular process is fairly constant in obliquity and size, but may vary within limits as to outline, being sometimes transversely elongated, in others vertically prolonged. The hinder crus of the lateral process starts from the arch in front of the anterior border of this process. Above and behind this, and behind the smooth area on the upper surface of the lamina upon which the second nerve lies, there is usually a vascular hole in a depression, marking the point of junction of the lamina and pedicle: sometimes this spot rises into a little rounded eminence, to which the thickened margin of the areolar posterior atlanto-axial ligament is attached. In one specimen this projects upwards as a kind of rudimental superior articular process, not really articulating with the atlas.

From this point backwards the upper edge of the lamina is thin for the weak atlanto-axial inter-laminar ligament. The inferior laminar ridge for the strong inter-laminar ligament between the axis and 3rd vertebra is much rougher, and differs from those of the subjacent vertebra in that it is at the level of the lower border of the lamina, whose inferior margin is seldom prolonged below it, as it is in the other vertebræ.

Pathological cases of ankylosis of the axis to the third vertebra, of the atlas to the axis, and of both to the occipital bone, are by no means uncommon, and are represented by specimens in our pathological museum. Of other diseased conditions simulating anomalies, the most interesting are those in which, after fracture of the dens, the upper part of that process seems to have become disintegrated, as in the curious case described by Friedlowsky (*Wiener Med. Jahrbücher*, x. p. 232, 1868).

In noticing the literature of anomalies of the atlas in my last paper, I omitted to refer to the cases of divided atlas published by Theile in the *Deutsche Klinik*, 25, 1853, and by Keen in the *Amer. Jour. Med. Sci.* for 1874, p. 412.

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## EXPLANATION OF PLATES IX., X.

### Plate IX.

Fig. 1. Upper surface of axis at 11th week × 5. *a*, cartilaginous body; *b*, bony rod in arch.

Fig. 2. Coronal section of axis at 16th week × 2. *c*, dens; *d*, bony nucleus in body; other letters as last.

Fig. 3. Coronal section of axis at 19th week. *d'*, united body nuclei; *e*, dens nuclei.

Fig. 4. Similar section at 22nd week.

Fig. 5. Unusual case of delayed union of lateral dens centres in infant of 5 months old.

Fig. 6. Axis at birth. *e'*, united dens centres.

Fig. 7. Axis of child 15 months old, seen from below. *f*, hypochordal nucleus.

Fig. 8. Coronal section of axis of 28 months child, showing hypochordal epiphysis.

Fig. 9. Axis of child 45 months old, showing the apical epiphysis, *g*, of the dens.

Fig. 10. Coronal section of adult axis, showing, *h*, the lenticular cartilage between the dens and the body of the axis; and, *i*, the inferior epiphysis of the body.

### Plate X.

Fig. 11. Elongated spine of axis, natural size. *a*, median superior ridge; *b*, inferior tubercle; *c*, lateral oblique surface; *d*, posterior surface; *e*, lateral tubercle.

Fig. 12. Rudimental spine in the axis of ancient Egyptian.

Fig. 13. Wide bituberculate spine in axis of Saxon, from secondary interment in Bowl's barrow, Wiltshire.

Fig. 14. Axis with acuminate spine.

Fig. 15. Axis with friction facet on superior ridge.

Fig. 16. Spine of axis with long lateral tubercles.

Fig. 17. Arterial foramen, round variety.

Fig. 18. Axis with exserted lateral processes.

Fig. 19. Arterial foramen, ovate variety.

Fig. 20. Axis with lateral processes under cover of upper articular surface.

Fig. 21. Axis with deficiency of outer wall of arterial foramen.

# Notices of New Books.

*The Hippocampus.* By Alex. Hill, M.D. *Philosophical Transactions*, vol. 184 (1893), B; pp. 389–429.

The author first considers the several views which have been held regarding the morphological relations of this structure, and then describes the hippocampus of several anosmatic mammals. His conclusions are—

1. That the fascia dentata is absent from the brains of *Hyperoodon rostratus* and *Monodon monocerus*. It is but very slightly developed in *Phocæna communis*. In *Phoca vitulina* its size is small.

2. The extension of the fascia dentata in the several members of the mammalian class varies as the relative development of their olfactory apparatus.

3. The relative representation of olfaction in brains of different species is shown by the ratio which the length of the hemisphere bears to its other dimensions.

4. The anterior commissure and fornix vary in thickness as the relative development of the rhinencephalon, although neither is absent in anosmatic brains.

5. There is no reason for associating the fascia dentata with the striæ longitudinales, gyrus subcallosalis, and gyrus geniculi, or for supposing that all these four structures belong to a single organ, which forms a part of the cortical centre for the sense of smell. The fascia dentata is a subcallosal structure: it alone disappears in completely anosmatic animals.

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*Ueber die feinere Struktur des Ammonshornes.* By S. Ramón y Cajal. *Zeitschrift für wissenschaftliche Zoologie*, vol. 56, 1893, p. 615.

After a detailed description of the microscopic anatomy of the cornu ammonis, fascia dentata or subiculum according to Golgi's method, the author summarises as follows:—

1. The cornu ammonis represents a portion of the brain cortex, but of a more complicated character in its superficial layers, simpler in its deeper layers.

2. The molecular layer of the cornu ammonis is richer in cell elements than is the cortex, for, in addition to the cells of Golgi's second type, there are certain triangular corpuscles and spindle-shaped cells.

3. As in the cortex, the nerve processes from the cornu ammonis are association, projection and commissural fibres.

4. Although the fascia dentata corresponds in essential features with the cornu ammonis, it yet possesses certain characteristics, the chief of which are that the axis cylinder processes of the granules present mossy thickenings and circumcellular tufts in the layer of pyramidal cells.

5. The association cells of the cornu ammonis and fascia dentata are divided into three kinds: large pyramidal cells with short branches; spindle and triangular cells with longer axis cylinders which end in large branched tufts; and irregular cells with very short nerve-branches which anastomose with neighbouring protoplasmic terminals.

6. A point of general interest consists in the fact that, while the bodies of cells with long axis-cylinder processes, such as are found in the cerebral cortex, Purkinje's cells of the cerebellum, and the anterior-horn cells of the spinal cord, are embraced by thick end tufts of collaterals and nerve fibres, the cells of Golgi's second type with short nerve processes never possess clear circumcellular envelopes.

Journal of Anatomy and Physiology.

# MORPHOLOGICAL PECULIARITIES IN THE PANJABI, AND THEIR BEARING ON THE QUESTION OF THE TRANSMISSION OF ACQUIRED CHARACTERS.

By R. HAVELOCK CHARLES, M.D., M.Ch., F.R.C.S.I., F.L.S., *Professor of Anatomy, Medical College, Lahore; Surgeon-Captain, Bengal Medical Service; Surgeon, Mayo Hospital, Lahore; Fellow of the Panjab University.*

IN the October number of the *Journal of Anatomy and Physiology*, vol. xxviii., in an article on the "Influence of Function, as exemplified in the Morphology of the lower extremity of the Panjabi," I pointed out certain characteristics of the bones of the lower limb of natives of the Panjab, whereby these could be distinguished from those of Europeans. I cited changes in the acetabulum, the shape and size of the inferior cornu of the facies lunata and of the cotyloid notch, &c. It was shown that the articular surface of the head of the femur was relatively and absolutely greater than in the European, and that it was prolonged so as to adapt itself to the modified facies lunata of the cotyloid cavity. That the *upper* surface of the internal condyle of the femur is partly articular. That the upper surface of the internal tuberosity of the tibia slopes considerably down and in, being never flat. That the external tuberosity has its condyloid articular surface convex from before backwards, and that the articular area is well prolonged down posteriorly. That a facet or facets were to be found on the anterior surface of the lower extremity of the tibia for articulation with similar surfaces on the neck of the astragalus during extreme flexion, or during extension or extreme adduction of the ankle-joint in the squatting and sartorial postures. That

on the neck of the astragalus were one or two facets—one external, and one internal—the latter continuous with the pyriform malleolar articular surface. That this pyriform malleolar area was to be found extending far forwards (and when so, it is concave from before back) on the inner surface of the neck, and is most in use during the sartorial posture, this position being rendered easier by the characters noted. It was also pointed out that the foregoing peculiarities in the morphology of the hip-, knee-, and ankle-joints of the Panjabi skeleton are owing to the influence of the squatting and sartorial postures which are commonly assumed by Orientals when engaged in their daily avocations, or when indulging in rest after their labours. It was suggested that the peculiarities might either be acquired or inherited.

Others have shown that Neolithic European remains, as regards facets on the lower extremity of the tibia and on the astragalus, present a marked contrast to the modern Western types.

It is highly probable that the Cave-dwellers of Europe, with prehistoric Man generally, sat upon the ground—in the sartorial and squatting positions: thus one can account for the anatomical markings found on their osteological remains.

The habits of Europeans of the present day, and for many centuries in the past, have changed, squatting on mother earth being a posture not adopted by any European race for ordinary purposes of work or rest.

The characters of the joints have also changed: the facets found on the tibia and astragalus of Neolithic skeletons are not to be seen on those of the present day in countries of the West. Why? The bones have been modified to suit the change of posture due to the adoption of the chair. No advantage would accrue to the European from the possession of facets or modified articular areas on his bones, fitting them for the squatting or sartorial postures. He uses neither, nor has he done so for ages. Want of use would induce changes in form and size, and so from generation to generation the small differences would be integrated till there would eventually be total disappearance of the modifications in question.

Were an European to adopt from his birth Oriental customs

as to these positions, doubtless the joints would undergo changes. In him the articular portion of the superior surface of the astragalus is "quadrate for the tibia, concave transversely, convex sagittally, wider in front than behind" (Macalister). This is the trochlea. The superior surface of the astragalus of his new-born infant is like unto it. In neither are extra facets present on the neck of the bone, nor is the inner portion of the articular surface prolonged forwards to correspond with the greatly anteriorly elongated pyriform malleolar area.

In my former paper, quoted in the foregoing, I have shown that the Panjabi astragalus (fig. 1), when contrasted with the European, differs considerably.[1] Now, if all the facets in question be acquired by the influence of function alone acting

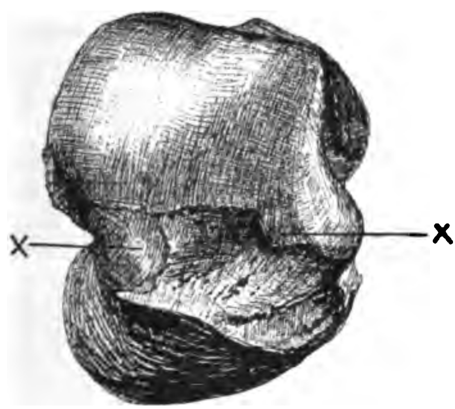



Fig. 1.

on the bones, it should follow that none of them, or of the peculiarities in the shapes of the articular surfaces found in the adult, could be present before the commencement of habits likely to produce such modifications in structure. That is, they should not be present in the joints of the *fœtus-in-utero*, in the child at birth, or in the infant up to such time as it can sit and squat of itself.

[1] Fig. 1 is a reproduction of the astragalus represented on p. 15 of the October number of this *Journal*, from an adult Panjabi.

If the rudiments of the modifications of structure shown by me are to be found in the fœtus and in the child at birth, there must be something beyond function to account for these variations from the European type.

It is a question then—have the peculiarities been acquired? or inherited? or inherited and developed by function?

The child of the European at birth has bones and joints of a like pattern with his progenitors.

The offspring of the Panjabi at its nativity has bones and joints similar to those of its forbears.

The Western issue is fitted for the customs of its lineage.

The Oriental also comes into the world to run his race in grooves worn by the habits of countless centuries, equipped with characters "profitable to the individual under its conditions of life"—"the tendencies conspiring to produce fit organisation."

The fathers follow the habits of their sires, and, having reached manhood, mature into their consanguineous types, begetting progenies which present at birth in miniature the osteological peculiarities of their racial protoplasts.

In paragraph 26 of the Resumé of my previous paper in the October number I have stated: "It is highly probable that all the foregoing peculiarities are acquired; but that heredity has no influence has yet to be proven."

It is generally admitted that function breeds structure—that is, structure can be influenced by habit. It is known that the habits of the present peoples of Europe differ from those of the ancient inhabitants. It is also known that morphological differences exist in the skeletons of prehistoric races as compared with modern nations of a similar geographical distribution. That is, races whose progenitors under different habits had certain osteological unconformities, have, under other customs, lost these same.

I have shown that Orientals—Panjabis—have similar bony markings to prehistoric Europeans of the Neolithic period: that the presence of the characters common to both may be explained by the practice of similar habits. I now point out—that the descendants of the former, retaining the same customs, preserve the markings; that the descendants of the latter, adopting differ-

ent practices, have lost the peculiarities of bony structure in question. It is known that the children of Europeans at birth possess none of these distinctions, whereas I demonstrate (figs. 2 and 3) in this paper that both in the fœtus and in the infantile Panjabi the foregoing points, so definite in the adult, are well marked.

Figure 2 is the left astragalus of a female Panjabi fœtus 8th to 8½ month. On the upper surface is shown an external facet prolonged from the trochlea, and an internal facet considerably prolonged forwards. On the inner surface is a pyriform malleolar facet. Figure 3 is from a female Panjabi infant æt. 3 months: the external facet is very distinct on the

Fig. 2.

Fig. 3.

upper surface of the neck, whilst the internal facet prolongs the trochlea forwards at its inner border. The marks × × are opposite the prolongations of the articular areas.

How is it possible for the astragalus of the infant—shown in fig. 2—to have its configuration as to these facets resembling that of the astragalus of an adult (shown in fig. 1) if heredity have no influence? Function as yet has not stepped in. It can be accounted for by the doctrine of Lamarck, that increased use of structures, enforced by change in environment, physical or organic, or both, reduces change in form, size, and structure of the organs; *and this change is inherited by the offspring*, and so from generation to generation small differences are accumulated until they become great.

It is not a question of the transmission of individually acquired characters from a father to his son; but it is of the transmission by accumulation of peculiarities gained by habit in the evolution of a particular racial type in which an acquisition has become a permanent possession—modified structure impressing some corresponding modification on the formation and polarities

of the units;—the units and the aggregates acting and reacting on each other, and securing a continuity of a useful inheritance.

It has been said that if "the effects of the use of certain muscles were transmitted to offspring, then definite results ought to have been frequently produced" (Wallace !). The *markings* on the Panjabi's astragalus, &c., are due to the use of certain muscles acting on the joints. *They* are the definite results produced—results found in the fœtus, found in the child at birth, found in the infant—and in all cases before function can possibly account for their presence! Subsequently they are perfected by use, as the individual advances to maturity; for one can generally tell the bodies, even before dissection, in which good and well-marked facets will be found, by noting whether callosities are present on the skin over the external malleoli and heads of the fibulæ, the styloid processes of the fifth metatarsals, the outer sides of the balls of the little toes, and over and below the tuber ischii;—the reason being, that it is over these bony prominences that pressure is greatest in the sartorial posture, which position affects most the long pyriform concave malleolar facets of the astragali, as well as those facets continuous with them on the upper surfaces of the necks, and which join behind with the trochleæ.

There is in *structure* a marked gain, "suitable to the individual under its conditions of life," rendering function of easier and better performance. Does it not depend on the inheritance of characters acquired by the ancestors in the long past?

I have dwelt at some length on the peculiarities of the astragalus, principally because the markings found on it are totally absent from the talus of the present European type. But there are portions of other bones which, as I showed in my previous paper, presented differences in the Panjabi as compared with the European—viz.: the head of the femur, its lower extremity, and the tuberosities of the tibia. In the latter there is a modification in the shape and extent of the articular surface, and a difference in the configuration of its upper extremity: not only is the epiphysis canted back, but there is also a considerable posterior obliquity of the superior portion of the diaphysis.

Fig. 4 shows the upper extremity of the front of a left femur from a Panjabi infant three months old. The encroachment of the articular surface on the neck of the bone is at once apparent, and an examination of fig. 4, on page 9 of the October number of the *Jour. of Anat. and Phys.*, vol. xxviii., will demonstrate that the peculiarity exemplified there in the adult Panjabi femur is present here in the infant to even a more striking extent, this being due to the smaller relative development of the neck in the child.

Fig. 5 displays the lower extremity of the back of the same bone mentioned above. It shows that on the *upper surface* of the internal condyle there is in the infant, as in the

Fig. 4.

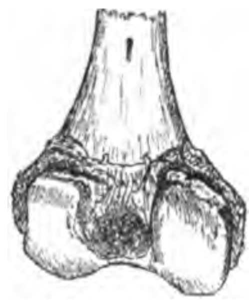


Fig. 5.

adult Panjabi (see fig. 5, "Influence of function on bones of lower limb," vol. xxviii. *Jour. of Anat. and Phys.*), (1) an articular portion, as well as (2) a roughness for head of gastrocnemius.

An examination of fig. 6 will show that the upper portion of the diaphysis of the tibia is oblique, and that the posterior slant of this extremity of the bone is still further increased by the backward incline of its epiphysis. Fig. 7 demonstrates that this obliquity is associated with a considerable *convexity* of the external condylar surface. The internal tuberosity is prominent posteriorly, and its upper surface is very obliquely placed; consequently, the tibial spine and condylar articular surface are quite visible, though this would not be the case in an European specimen placed in a similar position to that in fig. 6. The

backward curve is very obvious in the infant, and is quite as great relatively as in the adult bone.[1]

Why are these morphological peculiarities not found in the bones of the European adult and child? Is it because the Oriental inherits variations in structure acquired by his ancestors,

Fig. 7.

Fig. 6.

and transmitted, with accumulations due to continuity of like habits, as useful heritages? May I suggest this explanation of the foregoing facts? If so, the transmission of acquired characters is possible. *Q.E.D.*

Climate, surroundings, and usages have made the Oriental what he is; and if ordinary habits have so acted on his skeleton as to change the configuration of the bones, how much more must certain methods of thought not have altered the bias of his mind? Mentally and physically he is dissimilar to the Western. The integument is darker, and the Endo-skeleton differentiates him. Our thoughts are not his thoughts, neither are his ways our ways. It happens thus that the methods of the Asiatic are not always understood by the European, and the manners of the inhabitant of the West at times stink in the nostrils of the dweller in Cathay. Their morphological diversities are not devoid of interest, whilst volumes could be written as to variances in their customs, usages, and actions.

[1] [Since this paper was in type, I have received from Professor Havelock Charles, Lahore, a photo. of the acetabular region of an infant Panjabi æt. 3 months, which shows a deepening of the cotyloid notch, and partial bridging over of the notch by a prominent inferior cornu of the facies lunata, similar to that which he described and figured in the October number of this *Journal* in the adult Panjabi.—W. TURNER.]

## Resumé.

1. The bones of the lower extremity of the Panjabi adult have certain markings differentiating them from those of the European.

2. These markings are found on the bones of the fœtus, the infant and the child of the Panjabi.

3. Had they been due to the influence of function alone, it is reasonable to suppose that they would likely not be present till use had called them forth, and that they would appear gradually.

4. Subsequently, they are perfected by function as the individual advances to maturity.

5. These markings are not found in the skeleton of either the European adult or child.

6. They have, some of them, been found in the remains of Neolithic Man in Europe, but are absent in the bones of peoples of the present day of similar geographical distribution.

7. The habits as to sitting postures of Europeans differ from those of their prehistoric ancestors, the Cave-dwellers, &c., who probably squatted on the ground.

8. The sitting postures of Orientals are the same now as ever. They have retained the habits of their ancestors. The Europeans have not done so.

9. Want of use would induce changes in form and size, and so gradually small differences would be integrated till there would be total disappearance of the markings on the European skeleton, as no advantage would accrue to him from the possession of facets on his bones fitting them for postures not practised by him.

10. The facets seen on the bones of the Panjabi infant or fœtus have been transmitted to it by the accumulation of peculiarities gained by habit in the evolution of its racial type—in which an acquisition having become a permanent possession, "profitable to the individual under its conditions of life," is transmitted as a useful inheritance.

11. These markings are due to the influence of certain positions, which are brought about by the use of groups of

muscles, and they are the definite results produced by actions of these muscles.

12. The effects of the use of the muscles mentioned in No. 11 are transmitted to the offspring, for the markings are present in the *fœtus-in-utero*, in the child at birth, and in the infant.

13. The markings are instances of the transmission of acquired characters, which heritage in the individual function subsequently develops.

I have again to thank my friend Dr Dickson, of the Central Jail, Lahore, for the pains and trouble he has taken in photographing the specimens. The figures 2–7 are from wet specimens, on which the cartilages and synovial membranes had been preserved, presented by the author to Sir W. Turner, and are drawn from nature by Mr George A. Rorie, student of anatomy, who has also had Dr Dickson's photographs before him to refer to.

# AXIAL ROTATION OF ABDOMINAL AORTA, WITH ASSOCIATED ABNORMALITIES OF THE BRANCHES.

By C. C. BAXTER TYRIE, M.B., C.M. Edin., *Demonstrator of Anatomy, Leeds; late Demonstrator of Anatomy, Surgeons' Hall, Edinburgh.*

THERE is no region of the body where abnormalities in the vascular system are so common or so diverse in their nature as in the abdomen. Divergences from the ordinary accepted arrangement are so frequent, and in some cases the same forms of aberration recur so persistently, that they might be almost described as alternative varieties.

The *causes* of deviation from the generally accepted type may conveniently be classified under two heads, each of which admits of further subdivision:—

I. Persistence, or perverted development of fœtal arrangements—

(*a*) vascular, (*b*) visceral, (*c*) parietal.

II. Pathological changes—

(*a*) vascular, (*b*) visceral, (*c*) parietal.

Very rarely, however, is such a combination met with as in the following male subject dissected in the Anatomical Department, Surgeons' Hall, Edinburgh, last winter.

During the dissection of the abdomen my attention was arrested by the peculiar relationship of the common iliacs one to another, the right lying anterior to the left at the aortic bifurcation. Subsequent investigation demonstrated the following points.

The arch and descending aorta were uniformly dilated to a point immediately above the origin of the cœliac axis, where the vessel became abruptly constricted to the size of the subclavian artery, and maintaining this calibre, descended to the middle of the fourth lumbar vertebræ, where it bifurcated, the divisions occupying the relative positions previously stated.

## Branches of Aorta.

*Cœliac Axis*, two inches long, divided into *Hepatic* and *Coronary;* from the right branch of the former a trunk descended vertically to enter the upper border of the corresponding kidney, passing anterior to the suprarenal body (fig. 1, C, RH, LH).

*Splenic* had an independent origin from the aorta (fig. 1, S).

*Superior Mesenteric* arose from the left lateral aspect of the aorta, and was distributed in the usual manner (fig. 1, 1).

*Right Aortic Suprarenal* arose from the left anterior aspect.

*Left Aortic Suprarenal* arose from the posterior aspect rightwards (fig. 1, LS).

*Left Renal Arteries*, five in number (fig. 1, L1 to L5)—

1. "*Superior*" *Aortic Renal* arose from the posterior aspect, coursed over the anterior surface of the kidney, and terminated by piercing the cortex at the outer border.
2. "*Middle*" *Aortic Renal* disappeared in the hilum.
3. "*Inferior*" *Aortic Renal* arose immediately below and a little more posteriorly than the preceding, and had a similar course and termination.
4. This vessel was derived *from the Common Iliac*, coursed vertically upwards to the inferior internal angle of the kidney, then inclined outwards, crossed the ureter, and ended in the hilum.
5. *From the Colica Sinistra*, of about the calibre of a crow quill, entered the anterior surface of the kidney near its base.

*Right Renal Arteries*, three in number (fig. 1, R1 to R3)—

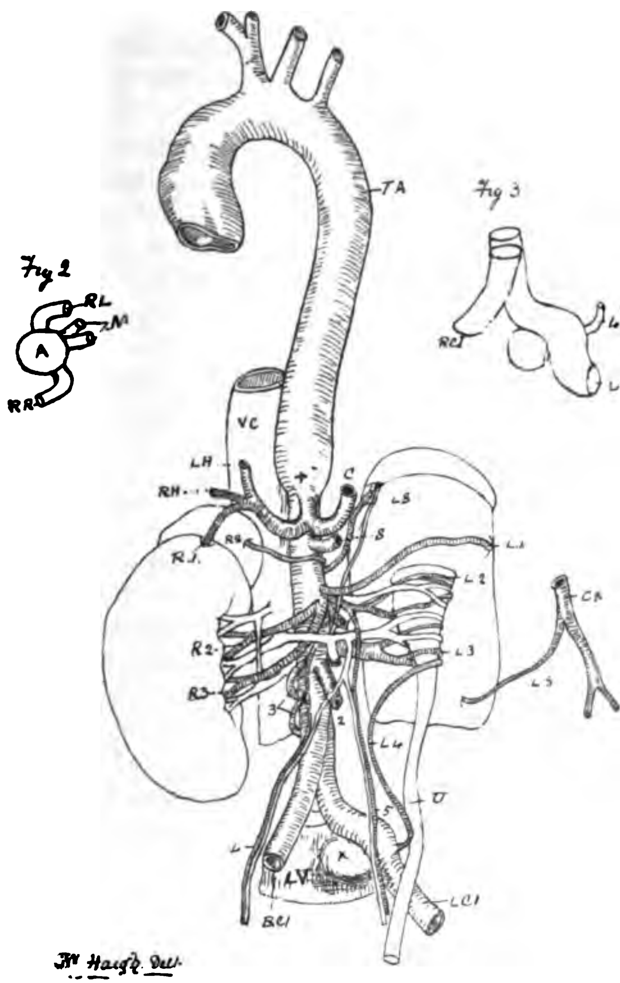
1. *Aortic* arose from the anterior aspect of the vessel.
2. *Aortic* also arose from the anterior aspect.
3. *Derived from the Right Hepatic*, as already described.

*Inferior Mesenteric* arose from the left lateral aspect, and was normal in course and distribution save for the renal derivative of the left colic (fig. 1, 2).

*Common Iliacs* were in antero-posterior relation at their origin, the left 4½ inches long, hooked round a sessile projection of bone on the anterior aspect of the fifth lumbar vertebra, and

was considerably dilated at a point corresponding to the origin of the fourth left renal artery (figs. 1, 3).

*Fig.* 1.




## VEINS.

*Left Renal Veins*—

1. "Superficial" crossed in front of the aorta to join the cava. It received the suprarenal, the common spermatic trunk, and the *Inferior Mesenteric*.

2. "Deep" coursed posterior to the aorta, and ended in the cava. It was joined by the second and third lumbar veins and a few twigs from the posterior abdominal parietes.

*Right Renal Veins* were three in number, the inferior being the largest, and all ended in the cava. The first and third communicated by a large cross branch, and there was thus formed, along with the cava, a venous ring through which the middle renal vein and one of the aortic renals passed.

*Spermatic Veins.*—The right crossed over to the left side of the aorta, and united with the left to form a common trunk, which ended in the left superficial renal vein (fig. 1, 4, 5).

Inferior mesenteric vein corresponded in origin to the distribution of the artery, but terminated in the left superficial renal vein. Although I made a most careful examination, I was unable to detect any compensatory radicle of the portal system.

## Abdominal Organs.

These were anatomically normal, save for the left kidney.

There was an enlarged prostate, the ante-mortem effects of which were visible in the dilated and fasciculated bladder and the slightly hydronephrotic condition of the right kidney.

The left kidney was apparently unaffected by the pathological condition, but conformed to a congenital type of malformation generally recognised, but meagrely described. It was almost perfectly rectangular (fig. 1) in shape, measuring 4 inches long, 2½ inches broad and 1 inch thick. The relatively small pelvis was placed in the middle of the anterior aspect.

## Parietes.

The spinal column in the dorsal and lumbar regions was affected by spondylitis deformans, but exhibited no marked abnormal curvature.

The extra or sub-peritoneal arterial plexus of Turner was very much in evidence, due no doubt to the condition of the lower part of the aorta.

The appearance of the abdominal aorta, the modes and points of origin of its branches, and the relations of the common iliacs to each other at their origin, tend to support the view that it had undergone axial rotation from right to left to the extent of 90°. Subsequent observation has brought before me minor degrees of the condition, but only in a limited portion of an artery. Whether the deviation was congenital, fœtal, or post-fœtal is open to argument, as is also the rotatory effect of the blood-stream passing from the dilated to the constricted portion. There was no condition observable in the region of the constricted portion which could be looked on as a cause.

An additional aortic renal is, according to Macalister, too common a variation to constitute an abnormality, and examples of a kidney receiving its blood from the aorta by three trunks are fairly common. In this subject the vascular supply of the kidneys is interesting on account of the plurality of trunks and their diverse origin. The derivation of a renal artery from the common iliac has often been observed, but the origins of renal arteries from the colica sinistra and hepatic are very rare, and are probably of little significance save as curiosities. In this subject I am inclined to think that the sinistral branch was a greatly enlarged capsular twig.

The large number on the left side is worthy of note.

On referring to the various authorities and examining the illustrations, I find divers numbers recorded, and curious sources figured.

A point which seems to have escaped notice, however, is the almost invariable association of an anteriorly placed renal pelvis with a plurality of arterial trunks.

This displacement of the pelvis on to the anterior surface of the kidney, and the deviation of the organ from the normal reniform shape, are generally in direct proportion to the plurality of vessels, and to a certain extent to their combined sectional area. I have been able to verify this association in several museum preparations and in the dissecting-room.

In the course of a series of examinations of the lower animals, in some of which the normal plurality of the renal arteries would lead one to suspect a more frequent occurrence of the condition, I have met the combination twice,—a minor

degree in a cat, and a fairly well marked example in *Didelphys virginiana*.

In regard to the association of this type of kidney with a plurality of vessels, I am of opinion that the greatly increased arterial pressure brought to bear on the kidney is responsible for a gradual rotation; and that the modification in shape is due to a concomitant moulding action exercised by the abdominal parietes against which the narrow outer border of the kidney comes to rest.

The termination of the inferior mesenteric in the left renal vein is interesting.

Its mode of termination is opposed to developmental principles. What would be the effect of the pouring of its blood into the systemic instead of the portal circulation? It could not have been very deleterious, as the subject was over 60, and died of cancer.

Perhaps the only explanation that can be offered of the peculiarity of termination is the singularly lucid one resorted to by a distinguished neurologist in similar difficulties—"an inherent perversity of development in the embryonal tissues."

I have to thank Mr Macdonald Brown, through whose generosity I am enabled to publish this, and to whose valuable suggestions I owe much; also Mr Haigh, Pathological Curator, Yorkshire College, for the figures, No. 1 of which is taken from a photograph.

Since writing the above, I have observed in a female subject a bilateral condition of the renal deformity. The pelvis on both sides was displaced on to the anterior aspect of the kidney, which was more or less rectangular in shape. The condition was better marked on the left than right side: on the left side there were five renal arteries, three of which were derived from the common iliac; on the right, three, all aortic in origin.

## EXPLANATION OF FIGURES.

### FIG. I.

T A, Descending aorta.
+ Constriction.
C, Coronary artery.
R H & L H, Branches of hepatic artery.
S, Splenic.
R S & L S, Right and left aortic supra-renals.
L 1, L 2, L 3, L 4, L 5,—Left renal arteries.
R 1, R 2, R 3,—Right renal arteries.
1. Superior mesenteric artery.
2. Inferior mesenteric artery.
3. Right lumbar arteries.
4. Spermatic artery and veins.
5. Left spermatic artery and veins.

R C I L C I, Right and left common iliacs.
C S, Colica sinistra.
V, Ureter.
× On bony projection from L 5.
V C, Inferior vena cava.

### FIG. II. *Aorta from above.*

R L, Right lumbar.
M, Mesenteric arteries.
R R, Right renal.

### FIG. III. *Section below Aortic bifurcation.*

R C I, Right common iliac.
L C I, Left common iliac.
4th L R, 4th left renal.

# MUSCULUS SAPHENUS. By C. C. BAXTER TYRIE, M.B., C.M. (Edin.), *Demonstrator of Anatomy, Yorkshire College, Leeds; late Demonstrator of Anatomy, Surgeons' Hall, Edinburgh.*

MUSCULAR anomalies on the anterior aspect of the thigh are so rarely met, that the following case is worthy of note; and is of great interest both as regards the genesis of the muscle, and the means by which its position was determined.

It occurred in a male subject (age 65). On reflection of the deep fascia of the thigh, my attention was arrested by the transverse disposition of what was evidently a muscular slip. Further examination showed the condition to be bilateral, and although similar in appearance, relations, and probably innervation, the muscle was better developed on the right than left side.

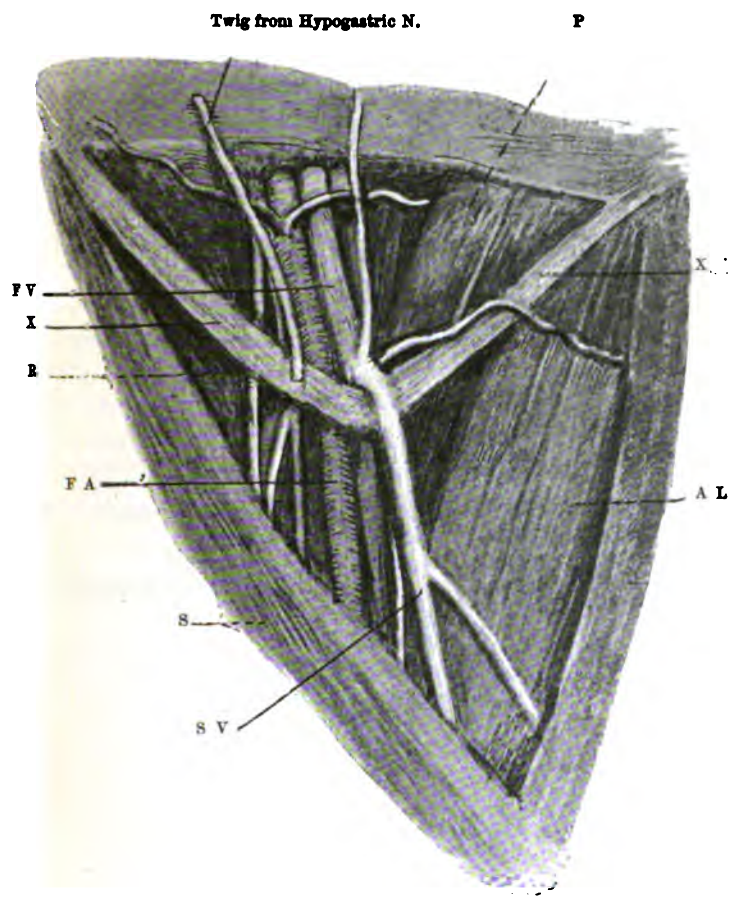
Tracing it from without inwards, its "origin" was found to be in direct continuity with the superficial fibres of the outer extremity of Poupart's ligament. The tendinous fibres of origin inclined downwards and inwards along the inner border of the sartorius for about an inch. Here, muscular fibres were substituted; and the muscle passing inwards over the iliacus and anterior crural nerve crossed over the bifurcation of the common femoral, at the inner side of which it hooked round the loop formed by the junction of the saphenous with the femoral vein, and ascending obliquely inwards over the pectineus and tendon of adductor longus, finally became blended with the inner end of Poupart's ligament. Tendinous fibres were substituted in the last inch.

The nervous supply was derived on the right side from the hypogastric branch of the ilio-hypogastric. The left nerve was not seen, being missed in the somewhat hasty dissection made to ascertain the nature of the structure.

The relation to the saphenous vein and opening is interesting: to the former, as it was in all probability the determinant of

the femoral position of the muscle; to the latter, as it bounded it inferiorly, but on a plane posterior.

The view that the muscle was a detached portion of the external oblique is supported by the blending of its "origin"




Musculus Saphenus.

and insertion with the extremities of Poupart's ligament, and by the fact that although in the region of supply of the anterior crural nerve, it was supplied by the ilio-hypogastric. The only explanation, I think, of which the condition admits, is that at

an early period of fœtal life the external somatic layer (extending, perhaps, further back than usual) was pierced by the internal saphenous on its way to join the deep vein. In the course of development a regression of the confluence has taken place, and the included muscular fibres have, as a consequence, been looped backwards.

From the appearance of the muscle, the probability of it being functionally active, and its relation to the vein, some effect on the vessel and its radicles would naturally be expected, but a careful examination did not reveal even a suspicion of varicosity.

I have been unable to find any previous record of this structure, and from its etiological relationship to the vein, have ventured to term it *Musculus saphenus.*

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EXPLANATION OF FIGURE.

F A, Femoral artery.
S V, Saphenous vein.
A L, Adductor longus.
R, Rectus femoris.
F V, Femoral vein.
S, Sartorius.
P, Pectineus.
X X, Musculus Saphenus.

# VARIETIES OF HYDROCELE OF THE *TUNICA VAGINALIS TESTIS* AND SOME ANOMALOUS STATES OF THE *PROCESSUS VAGINALIS*. By

JOSEPH GRIFFITHS, M.A., M.D., F.R.C.S., *Assistant to the Professor of Surgery in the University of Cambridge, Pathologist at Addenbrooke's Hospital.*

IN the clinical examination of simple hydroceles of the *tunica vaginalis*, it may be observed that they differ from one another not only in size but also in form: some are more or less globular; others pyriform, with a slight constriction at the junction of the lower broader part with the upper narrower end; while others still are simply ovoidal, with the larger end downwards.

It would seem that these differences in the shape of the distended sac of the *tunica vaginalis* are to be accounted for by the manner in which the serous membrane is disposed to the testicle and epididymis in each particular instance; and in order to display the varieties of disposition of the membrane in the natural state, it is only necessary to distend the sac with air, fluid, or some solid substance. In this manner the mode of disposition of the *tunica vaginalis* to the testis can be determined, and its outline can be delineated in each instance.

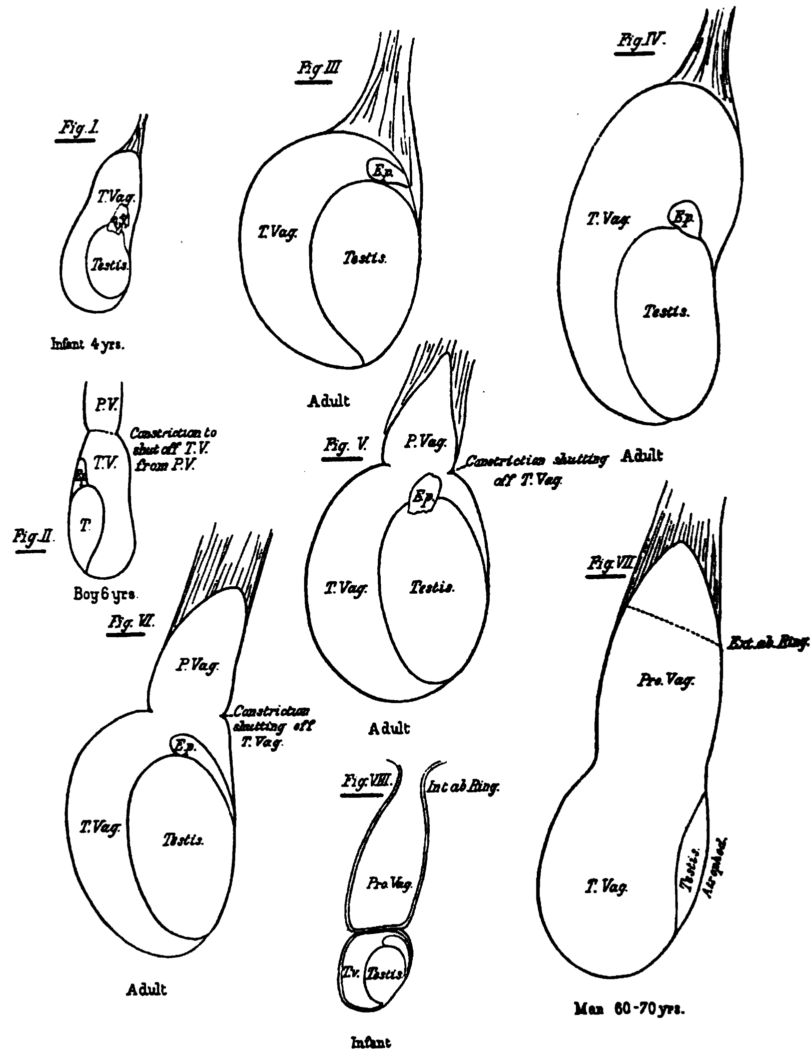
I have adopted the plan of distending the sac with air introduced by means of a special canula, which I formerly used in some experiments to determine the variations in the pressure of the cerebro-spinal fluid, and which was devised for me by Professor Roy.

By means of this canula I have distended the *tunica vaginalis* with air in each of a large number of testicles removed after death, from persons whose ages ranged from one to seventy years. After distension the whole was submerged in strong spirits. On the following day the canula was withdrawn, but the specimen, still distended, was replaced in the spirit, and kept there nearly a fortnight, when, with a long sharp knife, a section was made at or near the middle, in a longitudinal direction from before backwards.

## SIMPLE HYDROCELE.

In the young *child* the shape of the distended *tunica vaginalis* is almost constant. It is long, extending well above the testicle, at the upper level of which there is usually a slight

constriction in the sac, as is depicted in fig. I. The epididymis, as may be noted, is relatively larger to the body of the organ at this than at any subsequent period.




So far as I have observed, the *tunica vaginalis* is, proportionately to the testicle, larger in the child than in the adult, and its length is relatively greater than its breadth.

The slight constriction in the sac near the upper level of the testicle, noted above, is a constant feature in the distended sac of quite young children,—that is, children up to five or six years of age. At ten and later this is not present, nor does it exist, so far as I am aware, in the adult. At first this constriction might seem identical with the natural one that takes place at the point where the *tunica vaginalis* is shut off from the *processus vaginalis;* but this is obviously not the true explanation, for this slight constriction and that at the junction of the *processus* with the *tunica vaginalis* may exist side by side, as in the case from which the drawing shown in fig. II. was taken. In this specimen, which was removed from the right side of the body of a boy aged six years, both the constriction proper to the *tunica vaginalis* of the child and that which takes place at the line of separation from the *processus vaginalis* are well shown.

In the *adult* the distended *tunica vaginalis* assumes, as a rule, one of two forms, namely, (1) the more or less globular, in which the sac hardly extends above the level of the upper end of the epididymis, as seen in fig. III.; (2) and the other more ovoidal, in which the sac extends an inch or more above the level of the upper end of the epididymis, as seen in fig. IV.

I have not met with any other shape where the *tunica vaginalis* has been completely shut off from the *processus vaginalis*—a process which not unfrequently fails, as will be immediately shown. It is true that in the child, as may be gathered from figs. I. and II., the distended sac assumes a more or less pyriform shape, and that this is the typical child-form; but this form, which is normal to the child, is, I find, uncommon in the adult; and it is only found when the lower end of the *processus vaginalis* remains unobliterated and in free communication with the cavity of the *tunica vaginalis.*

Although the above (the spherical and ovoidal) are the two forms usually assumed by the distended normal *tunica vaginalis* of the adult, it must not be assumed that these forms are always retained in cases of hydrocele; for in hydrocele the chronicity of the malady and the effects of long-standing hydrostatic pressure, which is always greater in the lower than the upper segments of the sac, tend to distend the lower more than the

upper end, and consequently the sac becomes broader below than above, even if this were not so from the beginning. There is, however, another form which is occasionally met with in practice, namely, the *pyriform*. This is in a majority of cases due, so far as I have been able to determine, to incomplete obliteration of the lower end of the *processus vaginalis*, and the persistence of a free communication between its cavity and that of the *tunica vaginalis*. I have found three or more instances after death, and have seen a few in living subjects. In young children the *tunica vaginalis* when distended assumes a more or less pyriform shape. Although, as mentioned, similarly shaped tunics or sacs have not been found in the adult specimens examined, yet it is probable that a certain number of this form of hydrocele, which is now and then met with, results from a persistence of that condition found in children. Sir George Humphry, who first drew special attention to this pyriform shape occasionally assumed by the distended *tunica vaginalis* of the adult, in his article on the "Generative Organs" in *Holmes' System of Surgery*, first edition, supposed that it was due to the shape of the tunic, as, he says, may be proved by blowing air into it [*tunica vaginalis*]. He further remarks that this constriction—that is, the constriction between the upper narrow and the lower broader part—has often led to the supposition that there were two distinct sacs, or that there was a hernia in addition.

Curling, however, in his treatise on "Diseases of the Testis," attributes this shape to less resistance at the upper part of the sac, and considers the extension up the cord to depend in the main upon the length of time the hydrocele has been in existence.

As has been pointed out above, a certain number of these cases may be explicable upon the supposition that the pyriform shape found in young children persists throughout life, but the remainder—which perhaps constitute the majority—are in all probability to be explained only by such cases as the following:—

The testicle, which was removed from a young man of about 20 years of age, showed, after distension of the *tunica vaginalis*, a marked pyriform shape, the narrower part extending for about 1¼ inches up the cord, and the usual constriction was well pronounced,—more, of course, than would be the case when con-

tained within the scrotal tissues as in the living subject. A section of this, see fig. VI., shows the *tunica vaginalis* below and an unobliterated portion of the *processus vaginalis* above, the two cavities being continuous at the seat of external constriction, *i.e.* the point at which the *tunica vaginalis* should have been shut off from the *processus vaginalis*. There is here a distinct valve-like projecting ledge on the inner surface of the sac, which is due to the resistance of the walls of the sac to the pressure which has distended the cavity above and below.

I have two other and similar instances, both of which reproduced the pyriform shape when distended, and also showed the constriction in exactly the same place. One is represented in fig. V. Were it not for this communication between the *tunica* and the *processus vaginalis*, the sac of the former would be of a globular shape in each instance, and would thus resemble that which is seen in fig. III.

In this connection I may mention an interesting example of a typical pyriform hydrocele lately obtained from a man who died from cancer of the stomach in Addenbrooke's Hospital. The hydrocele, which was on the left side, had existed for many years. It was distinctly pear-shaped, with the usual constriction above the level of the testicle; but the narrower end extended upwards within the external abdominal ring, half way up the inguinal canal, where it ended in a blunt cone-like end. The walls of this hydrocele were much thickened, and they contained numerous calcareous plates of irregular size and shape, and the fluid was of a greenish colour, holding in suspension numerous cholesterin crystals.

In this case, as in those above related, the constriction was situated immediately above the level of the upper end of the testicle, which organ had suffered very considerable atrophy from pressure, there being no trace of epididymis visible within the sac. See fig. VIII.

## THE BILOCULAR HYDROCELE.

There is also another and well known form of hydrocele, namely, the bilocular, which may be regarded as an exaggeration of the preceding, the first example of which was described by

Sir Joseph Lister in the *Edinburgh Medical Journal* (1856), and of which many instances have since been reported by Humphry, Curling,[1] Kocher,[2] Beraud,[3] Bazy,[4] and others.

This form is characterised by being composed of two sacs, the one occupying the *tunica vaginalis*, and the other, which is often the larger, extending to a variable distance in the spermatic cord—it may be to the internal ring, and even beyond this point it may ascend in the abdominal wall between the fascia transversalis and the peritoneum. These two sacs communicate, as a rule, by a narrow opening at a point which corresponds to the natural line of constriction between the *tunica* and the *processus vaginalis*.

The constriction that occurs at the internal abdominal ring in the process of shutting off the *processus vaginalis* from the peritoneal cavity is well recognised, but that which occurs below, immediately above the level of the testicle, in order to shut off the cavity of the *tunica* from that of the *processus vaginalis*, has as yet scarcely received sufficient attention from anatomists and surgeons. In the preceding examples of the pyriform-shaped hydroceles in the adult, the situation of this line is well seen.

The degree of constriction varies in different instances and, accordingly, the aperture of communication between the upper and lower cavities.

It seems therefore pretty clear that these cases of bilocular hydroceles, one locule of which extends up the spermatic cord, are referable to incomplete obliteration of the *processus vaginalis*, and failure of the natural constriction at its lower end to shut it off from the *tunica vaginalis*.

This is the view adopted by Bazy,[5] who based it upon the results of the examination of 68 examples of testicles removed at all ages up to 13 years. In *two* of these he found that the *processus vaginalis* remained open up to the external abdominal ring, though, owing perhaps to his method of

[1] Curling, *op. cit.*

[2] Kocher, "Die Krankh. d. Männ. Geschlecht Org.," *Deutsche Clin. Chir.*, 1887.

[3] Beraud, *Arch. Gen. de Med.*, 1856.

[4] Bazy, *Arch. Gen. de. Med.*, 1887.

[5] Bazy, *op. cit.*

investigation, he did not show the line of constriction between the upper or *processus*, and the lower or *tunica vaginalis*.

It appears that the *processus vaginalis* may be shut off from the peritoneal cavity at the internal ring, while the rest of its canal to a greater or less extent may remain patent; on the other hand, the *processus* may also be shut off from the *tunica vaginalis* below, while the upper portion remains patent to the peritoneal cavity,—the shutting-off process having taken place at the lower line of constriction noted above (see figs. III. to VII.).

When the *processus* is thus shut off from the *tunica vaginalis* at this line, and when it remains open above, then there may occur a not unfrequent variety of congenital hernia, first described and figured by Scarpa. In this case the hernia does not reach the cavity of the *tunica vaginalis*, being separated from it by the obliterated lower end of the *processus*, which constitutes a kind of septum.

The following are interesting examples of this condition, which I lately placed in the Pathological Museum of the University of Cambridge.

In one of these the hernia was on the right side only, in the other there was hernia on both sides. As both show precisely the same conditions, I shall only describe one. It was in a child 2 to 3 years of age, who died of inanition. There was a hernial sac which extended down to the *testis*, and opened into the peritoneal cavity by a small opening large enough to admit the tip of the little finger. The sac, which was the unclosed *processus vaginalis*, and into which the *vas deferens* projected, was of uniform size down to the *testis*, where it was completely shut off from the *tunica vaginalis*, as seen in fig. VIII.

Hunter, in his monograph on the "Descent of the Testicle," expresses his opinion that the *processus vaginalis* begins to close above, and that the closure gradually proceeds downwards until it reaches the upper end of the testicle, where the process of obliteration ceases. This may be true of the normal mode of closure of the *processus vaginalis*, but certain it is that (1) the lower extremity closes first in some instances; (2) both extremities may close, leaving the intermediate portion

unobliterated; and (3) the upper end only may close, all below remaining patent, and in free communication with the *tunica vaginalis.*

## MULTILOCULATED VAGINAL HYDROCELE.

I have been fortunate enough to discover in the post-mortem room four examples of the multiloculated variety of hydrocele

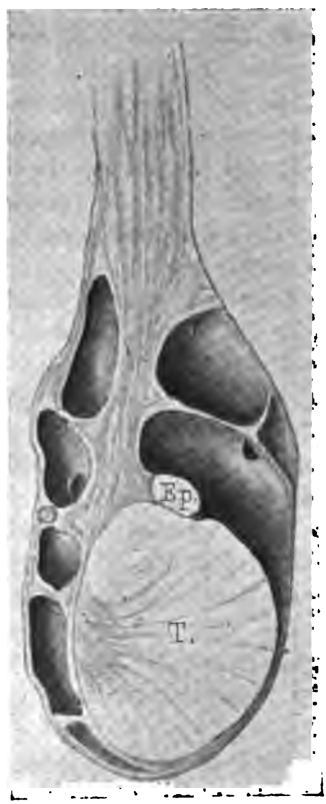



FIG. IX. Multiloculated Vaginal Hydrocele in a Middle-aged Man.

of the *tunica vaginalis,* which is rarely if ever recognised in practice; accordingly, I venture to give an account of them here.

They are, I need hardly point out, quite distinct, both in their

situation and general characters, from the multiple spermatoceles (see *Jour. of Anat. and Phys.*, vol. xxviii. p. 107). The *first* example (see fig. IX.) was found on the left side in a man aged 69 years, who died from the effects of fractured ribs. The *tunica vaginalis* contained a small quantity of serous fluid, which by being pressed from one part to another, produced irregular bulgings of the sac such as I had not before observed. I, therefore, distended the sac by the method above described and found, after hardening in spirit, the condition depicted. There are in this at least seven locules, varying in size, and separated from one another by thin septa, which are perforated by small, circular, smooth-edged holes of about $\frac{1}{8}$ in. in diameter. In that manner all the locules communicate with one another.

The *second* example was also from the left side of a man aged 52 years, who died from chronic alcoholism. Here, again, unequal bulgings of the *tunica vaginalis* by the contained serous fluid was observed; and after distension of the sac and hardening, a very marked instance of multiloculated vaginal hydrocele was found.

The *third* was obtained from the left side of a man aged 63 years, who died from cancer of the pylorus. This hydrocele was of long standing, and it had been tapped on at least two occasions. The sac bulged at its upper and fore part, as if it were made up of several distinct locules. After distension with air, the bulged appearance of the upper part of the sac became more pronounced. On section it was found that the *tunica vaginalis* was bulged outwards in several places; and in one place a large cavity, which communicated with the general cavity by means of a small opening, was seen.

The *fourth* was removed from the right side of a man aged 54 years, who died of ruptured hydatid cyst of the liver. Similar bulgings to those in the previous cases were observed. After distension of the sac with air, a vertical section showed a good example of this variety of multiloculated hydrocele. The drawing is represented in fig. X., in which several large locules are seen. Some of these communicated with one another, and with the general cavity, by means of large wide openings, while others had only small, round, smooth-edged holes, as noted in the example first described.

It would seem probable that in all the above examples the locules were in the first instance the result of localised bulgings of the tunica, and that subsequently the bulgings became distinct locules, having in many instances only small openings of

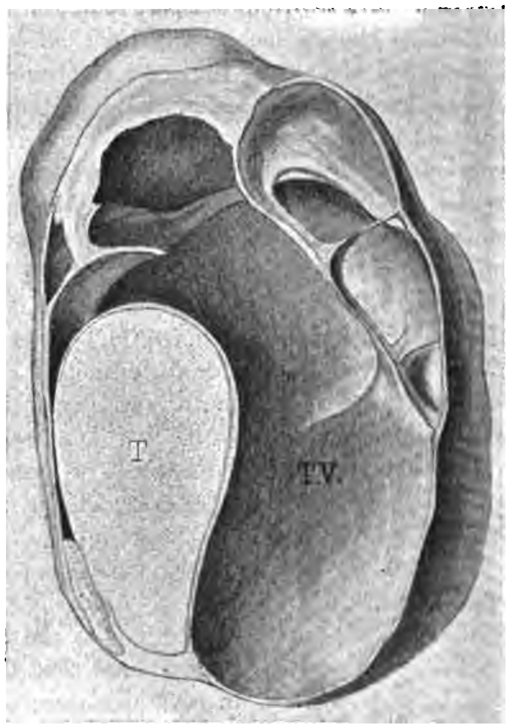



FIG. X. Multiloculated Vaginal Hydrocele in a Man 54 years.

communication between their cavities and that of the general tunic.

Another variety of multilocular vaginal hydrocele that I have met is formed by incomplete septa, evidently the result of previous inflammatory attacks between the visceral and parietal layers of the *tunica vaginalis* subdividing the cavity into two or more parts.

The multiloculated variety of vaginal hydrocele is not unknown, or at any rate some forms of it; for in the first edition

of *Holmes' System of Surgery*, Sir George Humphry mentions a case of hydrocele which he dissected, and in which he found numerous pouches on the external surface of the sac; these pouches communicating with the general cavity by means of small openings. But this is, so far as I am aware, the only instance of its kind described; yet the condition must be of not unfrequent occurrence, though its detection either in the living or in the dead person is not an easy matter. It may be observed, however, that a distinction between a simple and a multilocular vaginal hydrocele during life may have some practical bearing, and may explain some of the cases of failure to cure by injection; and the occasional existence of these complex vaginal hydroceles may indicate the importance of shaking the scrotum vigorously after the injection of iodine or other substance, so that the fluid may come into contact with each and every part of the sac wall.

I may further add, that I have frequently noted minute sac-like protrusions of the serous coats of the *tunica vaginalis*, and these are most frequent at the line of reflection of the parietal on to the visceral layers. Occasionally they are found towards the upper and front part of the sac, but very rarely in the lower half of the tunic.

Beraud[1] described a variety of hydrocele which he called the "Hydrocele Diverticulaire," and in which a pouch of large size was found in front of the *tunica vaginalis*, and this pouch communicated with the general cavity by means of a comparatively small opening. Being interested in the manner in which this diverticulum arose, he distended, in many instances, the *tunica vaginalis* with wax, and so obtained accurate impressions of their interior. These impressions showed that not unfrequently there existed small bulgings in the parietal layer of this serous membrane, and he thought that a further growth of one of such bulgings gave rise to the large diverticulum.

## CONCLUSIONS.

1. That in the adult the distended *tunica vaginalis* usually assumes either a spherical or an ovoidal shape.

[1] Beraud, *op. cit.*

2. That in the child the sac of the tunica vaginalis is almost always of a pyriform shape, with a slight constriction near the upper level of the testis.

3. That this pyriform shape when met with in the adult is due either to the persistence of the condition found in the child, or to incomplete obliteration of the lower end of the *processus vaginalis*, and the occurrence of a free communication between its cavity and that of the *tunica vaginalis*.

4. That the bilocular form of hydrocele occurs when the *processus vaginalis* remains unobliterated, being, however, shut off from the peritoneal cavity above, but communicating with the *tunica vaginalis* by an opening of variable size, depending upon the degree of constriction at the line of junction of the *processus* and the *tunica vaginalis*.

5. That there is occasionally met with a multiloculated variety of simple hydrocele of the *tunica vaginalis*, in which the locules arise either from bulgings of the serous membrane, or from the formation of incomplete septa between opposed parts of the parietal and the visceral layers.

# CASE OF LEFT KIDNEY DISPLACED AND IMMOVABLE. By W. F. FARQUHARSON, M.B. Edin., *Assistant Medical Superintendent, Counties' Asylum, Carlisle.*

CASES of displacement of the kidney into the lumbo-sacral region have from time to time been recorded in this *Journal.* Professor Howden described (vol. xxi. p. 551) a specimen of misplaced right kidney which he examined in a subject dissected in the Practical Anatomy rooms of the University of Edinburgh, and he refers to another case seen by Prof. Greenfield in a patient who died in the Royal Infirmary. He also gives an analysis of the cases of pelvic displacement of the kidney previously recorded. In the January number of the *Journal* for the present year Mr Macdonald Brown describes a closely similar case of misplacement of the right kidney.

The following case has come under my notice since the beginning of the present year.

It occurred in a young woman 22 years of age, who died of phthisis pulmonalis.

The right kidney was normal in shape, position, and blood-supply; it weighed 3 oz.

The left kidney was misplaced; it lay in front of the bodies of the 1st sacral and 5th lumbar vertebræ and the lower half of the body of the 4th lumbar vertebra. It was slightly to the left of the mesial plane. The upper portion of the left border overlapped the psoas muscle, but the greater part of the kidney was internal to the muscle. The upper extremity of the kidney lay over the bifurcation of the aorta. The organ was covered in front by the peritoneum, and was fixed in position by areolar tissue, there being practically no mobility. The long axis was almost vertical, but the usual arrangement of the organ was reversed; the convex border looked towards the right, and the hilum was directed towards the left side. The ureter entered the pelvic cavity in front of the lower extremity of the kidney, extending downwards from the hilum, which, covered with a layer of fat, was situated on the left and anterior part of the

organ, somewhat nearer its upper than its lower extremity. On its anterior surface, which was convex, the organ was distinctly lobulated. There were a small bean-shaped upper lobe, and a lower lobe more irregular in shape and larger than the upper, from which it was separated by a deep groove on the outer, aspect of the kidney; forming the back wall of the hilum was a third or central lobe of small size, tongue-shaped, and projecting between the upper and lower lobes, from which it was separated by deep sulci. The lobulation was not marked on the posterior surface of the kidney, which was quite flat.

On removing the fat which lay over the hilum, the upper termination of the ureter was seen to present some peculiarities: just before reaching the hilum it became dilated and funnel-shaped, and then immediately split into branches, which again subdivided and were distributed around the circumference of the hilum, passing to the apices of the pyramids.

The blood-supply was abnormal. Two branches were given off from the aorta to the left kidney. The larger of these arose from the left side of the aorta a short distance above its bifurcation, passed downwards behind the upper lobe, and entered the kidney on its left border at the hilum: it was accompanied by a vein opening into the inferior vena cava; a short distance from its termination this vein received a branch which passed from the hilum over the upper lobe of the kidney. The smaller artery arose from the right side of the aorta just at its bifurcation; it passed to and along the groove between the upper and lower lobes of the kidney to the hilum, where, like the other artery, it broke into branches: it also was accompanied by a vein opening into the inferior vena cava.

The kidney was irregularly triangular in shape; it was smaller than its fellow, weighing only 2 oz.

On section, the kidney structure appeared normal.

The suprarenal capsules occupied their usual position in the abdomen.

The ovaries were unusually long and narrow; but there were no other abnormalities of the genital organs, such as are sometimes found in similar cases.

## UNUSUAL MALFORMATION OF THE HEART. By R. J. Probyn-Williams, M.D., *House Physician, General Lying-in Hospital, York Road, Lambeth.*

The specimen described was removed from an infant, born at full term, at the General Lying-in Hospital.

The labour was normal; but the infant was cyanosed from the first, and required stimulation and artificial respiration before it could be made to breathe naturally.

It lived in the hospital for a fortnight, and died at the end of another fortnight from the time of its discharge.

During the whole of this period it was always in a more or less cyanosed condition—occasionally becoming almost black and intensely cold; but on these occasions it would revive in a few minutes after the application of heat and a little brandy.

The infant wasted more and more, and died gradually four weeks after its birth.

On examination during life, the apex of the heart was found to be to the right of the sternum; but repeated auscultations were made without any murmur being discovered. A patent foramen ovale was suspected, and consent to a partial *post-mortem* examination was obtained from the parents after some difficulty.

It is to be regretted that, owing to the rapidity with which the heart had to be removed, some of the vessels were not preserved which afterwards one would have wished to investigate.

On opening the thorax the heart was seen to be of the normal size, but the apex was to the right of the mesial plane; and the whole axis of the organ was the reverse of the usual one.

It was not till the auricle was opened that it was discovered to be single. It is about the usual size of the two together, and has a right and a left appendix; and its walls are of normal thickness.

No trace of a septum was at first noticed; but after preparation and stuffing out the cavities, a small flap situated about the middle of the upper part of the posterior auricular wall was discovered. This is evidently an abortive attempt at the formation of a septum; and on holding the specimen in a certain position,

it is noticed that in the middle of this is a thinner part—a rudimentary fenestrum ovale.

The auricle is separated from the ventricles by a vestibule common to the three cavities, and on looking from above one sees at the bottom of this vestibule the ridge of the inter-ventricular septum, with the openings into the right and left ventricles on either side. The cavities of the two ventricles are normal in size, as is also the thickness of their walls; and there are no perforations in the inter-ventricular septum.

The only valves in the interior of the heart are two in number.

They arise from a ring forming the demarcation between the auricle and the auriculo-ventricular vestibule, and are situated one over either extremity of the inter-ventricular septum.

Single above, each valve before reaching the septum divides into two parts, one going into each ventricle.

In structure these resemble an ordinary mitral or tricuspid valve.

The arrangement of vessels is very unusual. Into the auricle opens only one vessel, the superior vena cava, which is larger than usual. At the upper part of the right ventricle, very close to the auricle, is a rudimentary pulmonary artery, which is not patent at its cardiac end.

The aorta arises from the left ventricle, and is normal. It gives off a well-developed ductus arteriosus, which is joined by the rudimentary pulmonary artery, and which divides later into the two pulmonary arteries. On the left side there is a pulmonary vein, which apparently must have opened into the superior vena cava, as there is no other opening by which the blood could have reached the heart, and the vein was not connected with the aorta, the other of the only two cardiac openings.

On the right side there is no definite pulmonary vein—there being only a rudimentary loop going from one part of the lung to another. Thus for all practical purposes the heart consisted of two cavities, one auricular and one ventricular—as the right ventricle has no vessel of exit.

The course of the circulation must have been as follows:—

Starting from the aorta, blood passed from the ductus arteriosus to the lungs, and from the divisions of the aorta to the whole of the body.

All the systemic veins had apparently eventually ended in the superior vena cava, and with this venous blood must have mixed the arterial blood from the left lung. Thus the blood


FIG. 1.

[*Looking down on Heart and Lungs from above.*]

*a* Left Lung.
*b* Right Lung.
*c* Trachea.
*d* Ductus Arteriosus.
*e* Aorta.
*f* Pulmonary Vein (cut short).
*g* Pulmonary Artery, not patent at cardiac end.
*h* Left Ventricle.
*i* Single Vena Cava.
*k* Right Ventricle.
*l* Common Auricle.

can have been purely arterial in no vessel of the body with the exception of the left pulmonary veins up to their junction with the superior vena cava.

The blood in the lower part of the vena cava, the auricle, both ventricles, and all the systemic arteries must have been mixed

arterial and venous, and in the systemic veins, of course, purely venous.

After considering these points, it is of small wonder that the infant was cyanosed during life. It is curious that there is no trace of vessels returning blood from the right lung—for both lungs had evidently been used for the purpose of respiration—unless it returned by the bronchial veins to the superior vena cava.

This case is, I believe, unique; as I have not been able to discover any such specimen in a museum, nor a description of one in any literature of the subject.

It resembles very closely a diagram in His's *Anatomie Menschlicher Embryonen,* vol. iii. page 150, fig. 98, and copied into *Quain's Anatomy,* vol. i. part 1, fig. 173A.

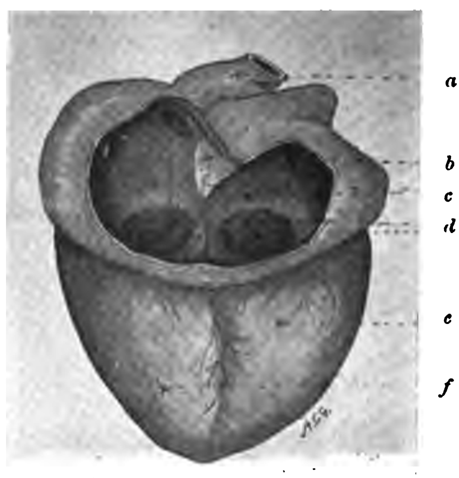



FIG. 2.

[*The Heart from in front and above, part of the Auricular Wall removed.*]

*a* Single Vena Cava.
*b* Abortive Auricular Septum.
*c* Common Auricular Cavity.
*d* Auriculo-Ventricular Apertures.
*e* Left Ventricle.
*f* Right Ventricle.

I am indebted to Dr Arthur Giles for the accurate drawings of the specimen that he has kindly made for me.

# SOME VARIATIONS IN THE FORAMEN OVALE IN THE HEART OF THE SHEEP. By SYDNEY D. ROWLAND, B.A., *Downing College, Cambridge.* (PLATE XI.)

WHILST engaged in demonstrating in Professor Foster's class at Cambridge last November, I came across a heart of a sheep which presented such unique features in the arrangement of the foramen ovale, that I was led to take the matter up, and to push it, if possible, to its logical conclusion. I subsequently examined over one hundred specimens with the following results.

All attempts to ascertain if the peculiarities noted were confined to a particular breed of sheep have proved, as yet, fruitless. This is owing to the peculiar methods in vogue in the meat trade, but some endeavour was made in this direction. The butcher who supplied the hearts to the laboratory was requested to procure specimens of hearts of all the different breeds of sheep that came in his way of business. These were examined, but with negative results. Until, then, more positive evidence is forthcoming, the question of breed must remain in abeyance.

The conditions of interest met with are the persistence of a patent foramen ovale, together with some arrangement for valvular protection, and the peculiar features of such valves.

In the specimen which first attracted my attention, the following is the condition:—

The foramen ovale is circular in outline, and measures 2·5 cm. in diameter. The valve consists of a membranous flap 3 cm. in length and 2 cm. in diameter, and is attached round about four-fifths of the opening, the antero-inferior one-fifth of which is free from valve and uniformly rounded. The free edge of the valve is prolonged at intervals into fibrous cords, which are attached in groups of four or five to the auricular wall just above the line of origin of the mitral valve. These cords

are not inserted directly into the wall of the auricle, but into small muscular columns, in precisely the same way as the chordæ tendineæ of the atrio-ventricular valves are inserted into the papillary muscles. The presence of muscle in these columns was proved by teased preparations stained and examined microscopically, and the scars left by cutting them away from the auricular wall may be seen in the Plate.

Two other examples of this arrangement were found, but not so marked as in the specimen first observed: thus some of the cords apparently hung quite freely in the auricular cavity; these, of course, might have been attached in a similar way to the above during life, but as the specimen only came to me after having been dissected by one of the members of the class, no positive statement can be made. The disposition of the valve was in all cases such as to prevent the flow of blood from the left into the right auricle: this is consistent with what we know of the relative pressure in the two auricles, that in the left being the higher.

Six other specimens were obtained exhibiting peculiarities, but as these were only modifications of one general plan, they may be described collectively. They may be divided into two classes—those in which the foramen ovale was open but small, and those in which the membrane which normally closes it was perfect, yet weak. In the first of these classes, of which there were two specimens, the aperture was about 1 cm. in diameter, and was prolonged into an oblique funnel, lying in the auricular septum, as is usual in cases of open foramen ovale; but in nearly all cases distinct cords were present, connecting the free thin (left) edge of the funnel to the auricular wall. In the second class similar cords were present, but proceeding from those parts of the membrane which were weakest.

In all the cases, then, we have an arrangement of cords, or of cords and muscles when the play of the valve is large, which would obviously take an important share in securing the efficiency of the valve by preventing reversion into the right auricle. In those cases in which there was no opening, the cords would play an equally important part in strengthening the membrane, and by limiting movement, diminish the chance of the rupture by sudden shock.

From what structures normally present in the heart can we derive this arrangement of valves and cords? That the specimens form a progressive series in complexity of the same fundamental structure will, I think, be admitted. The embryonic septa naturally suggest themselves as the basis from which the valve might have been derived, but Born has shown that the foramen ovale is an entirely new development in the atrial septum, the septum superius completely fusing with the septum intermedium. Rokitansky has described the closing of the foramen ovale at birth as taking place by the formation of a fenestrated membrane, the fenestræ of which subsequently close up.

But if this closure were imperfect the condition observed might very easily and simply result, by the persistence of that portion of the membrane that lies between neighbouring fenestræ as the cords, and that part of the membrane in which the fenestræ closed completely as the valve flap. The funnel condition is easily explained by supposing that the lower border of the foramen grows to meet the upper, the cords retaining their original position of insertion.

The series of changes which are here supposed to take place are adequately represented by the series of specimens.

Such, then, is the probable origin of the valve and its accessories.

The great point of interest in connection with these variations is, however, their almost exact resemblance to the condition of things met with in the atrio-ventricular valves. In both cases we have identical arrangements for preventing eversion of the valve flaps, viz., chordæ tendineae and musculi papillares. But in the case of the mitral and tricuspid valves we have ample ancestral precedent to fall back upon as an explanation: such is not the case in the valves described above. It seems, then, that such a complicated and highly specialised arrangement can arise without any ancestral precedent; why, then, quote it as an explanation of the specialisation in the atrio-ventricular valves, as would surely be done by anybody who was asked to explain the origin of the mechanism?

Similar results can only be produced by similar causes; we have therefore to look for such conditions as are common in

the ontogeny of both valves as a cause which could have produced them.

It is not yet possible to say what these causes are, and the question must be left in this position; but as it seems to me to be one of great suggestiveness, I have ventured to describe it thus briefly, hoping it may afford material for maturer consideration than I am able to give it.

In conclusion, I wish to express my thanks to Dr H. Gadow and Mr W. Bateson for much kindly advice and assistance.

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## EXPLANATION OF PLATE XI.

[The figures are all drawn to the same scale, and are of natural size.]

Fig. 1.—View of auricular septum from the left auricular side. *a*, *b*, position of scars left by removal of papillary muscles attached to cords *f* and *g*; *h*, papillary muscle.

Fig. 2.—View of same septum from right auricle, showing the obliquity of the funnel, through which a style is passed.

Figs. 3, 4.—Similar views of a typical example of those cases in which the opening was much reduced. The area inclosed by the dotted line is that of greatest weakness. *c*, the insertion of the larger of the cords, which was distinctly auricular. *d*, *e*, insertion of lower end, also auricular.

Fig. 5.—Left auricular view of a typical example of the third class of cases mentioned. Foramen completely closed. Cords well marked. I have seen this arrangement in a great number of hearts, including two human specimens.

## ABNORMAL STERNUM. By Professor A. M. Buchanan,

*Anderson's College, Glasgow.*

Varieties in the sternum are by no means uncommon in regard to the form of the whole bone, its length, the form and structure of the metasternum, the presence of a foramen sternale in the mesosternum and metasternum. The presence of a fissura sternalis is rare. Entire absence of the bone has even been noted.

A condition of ossification like that described in the present note must, I think, be comparatively rare.

The bone was removed from the body of a young girl æt. 4½ years, who had died from extensive tubercular disease of the abdomen.

Before maceration it was noted that the metasternum (which was entirely cartilaginous) measured 2 inches, and had a small foramen situated in its centre. During maceration it broke off at the seat of perforation, so that the illustrations only show the upper half of the original piece.

After maceration the following was found to be the condition of the bone:—

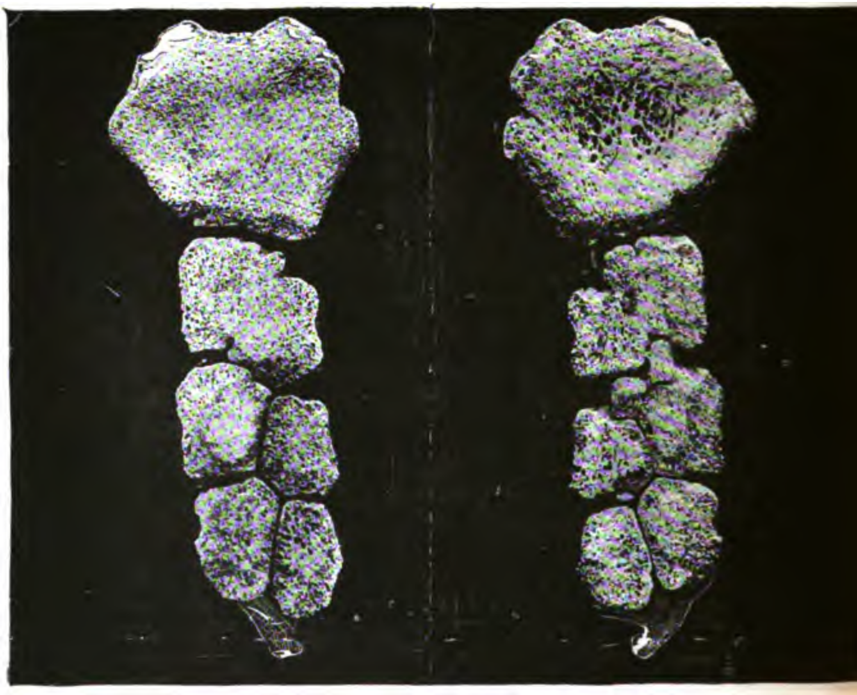
| | | |
|---|---|---|
| Length (exclusive of part broken off), | 4¾ | inches. |
| Length of presternum, . . . | 1½ | „ |
| Length of mesosternum (right side), | 2⅝ | „ |
| Length of mesosternum (left side), . | 2¾ | „ |

The presternum was entirely ossified.

The mesosternum was composed only of three transverse segments, all ossified. The first segment was single. Each of the second and third transverse segments was composed of two parts, separated from each other by a fissure running from above downwards, and equally apparent on the anterior and posterior surfaces. The right division in each case measured ⅞ of an inch in length and ⅝ of an inch in breadth. The left division of the second piece measured ¾ of an inch in length and

⅝ of an inch in breadth. The left division of the third piece measured ⅞ of an inch in length and ½ an inch in breadth.

On the posterior aspect of the mesosternum, and in the interval between the first and second transverse segments,



there were two distinct osseous nuclei, which were placed obliquely, each measuring ¼ of an inch in length and ⅛ of an inch in breadth.

The costal depressions on the sides were situated as follows :—

1 on presternum.
1 between presternum and first segment of mesosternum.
1 between first and second segment of „
1 between second and third segment of „
1 at upper part of side of third segment of „
2 on side of metasternum (placed close together).

THE FŒTUS OF *HALICORE DUGONG* AND OF *MANATUS SENEGALENSIS*. By Professor Sir WM. TURNER, F.R.S.

a memoir on the placenta of the Australian Dugong, communicated to the Royal Society of Edinburgh in 1889,[1] I gave ort description of the external appearance of the fœtus ined in the gravid uterus, and also referred to a much ger embryo. For both of these valuable specimens I was bted to C. W. de Vis, Esq., M.A., the Curator of the nsland Museum, Brisbane. I did not publish a figure of smaller fœtus, but I produced a profile view of the larger as cupied the sac of the amnion, which was, however, on too a scale to permit of much detail being given. So far as I w, no other drawing of a fœtal Dugong has up to this time figured, except the profile of a young fœtus, 27·8 centimetres in.) long, which Dr Paul Harting published in his memoir he ovum and placenta of this animal.[2] I have also in my ssion the head of a third Australian fœtus, intermediate in to those above referred to, which was collected during the ge of H.M. ship "Challenger," and was given to me by the te Sir Wyville Thomson. Since the publication of my memoir above referred to, I have had drawings prepared of these specimens, and have to thank my pupil Mr George A. Rorie for the care he has taken in their delineation. As the embryos of the Dugong are difficult to obtain, and seldom seen in museums, and as the animal itself is apparently on the way to become extinct, a reproduction of these drawings, with a description, will doubtless be of interest to anatomists.

I avail myself also of this opportunity to reproduce drawings, for which I am also indebted to Mr Rorie, of the fœtus of a Manatee presented to me many years ago by a former pupil, Dr Mackenzie, who obtained it whilst acting as surgeon to one of the trading stations on the West Coast of Africa.

[1] *Transactions*, vol. xxxv. part ii. No. 17.

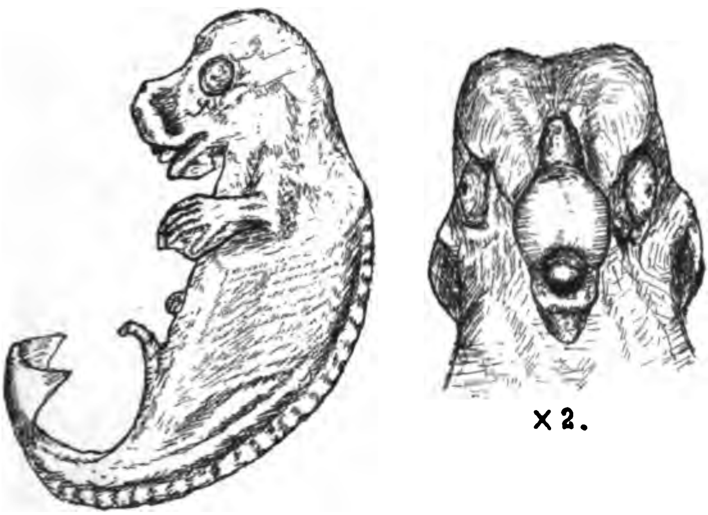
[2] Het Ei en de Placenta van Halichore Dugong, *Graduation Thesis*, Utrecht, 1878.

## EXTERNAL CHARACTERS.

A. *Halicore Dugong.*—*a.* The smallest fœtus of the Dugong measured 14 centimetres ($5\frac{1}{2}$ inches) from the muzzle along the curve of the head and back to the mid-point of the tail. It was a male, with the head bent downwards on the front of the thorax, and the tail curved forwards on the front of the abdomen. The surface of the skin was a pale drab colour, quite smooth, and with no hairs visible; but, with a simple lens, minute spots could be seen, which probably marked the site of hair follicles. The skin did not exhibit any of those shallow circular or oval depressions which Harting observed on the surface of his specimen, and which he ascribed to the pressure of round or oval bodies projecting from the inner surface of the allantois lining the chorion. In profile the head showed a distinct bulging in the frontal region, and was then slightly concave forwards to the nostrils, which opened by two small orifices, 3 mm. above and behind the muzzle. When examined from the front the muzzle was seen to be bounded by a well-defined border of skin, and its surface was slightly convex, smooth, and without furrows. At its upper part the muzzle sloped backwards to the nostrils, whilst below it was cleft into two lateral lips, between which a mesial process was seen projecting to the surface of the muzzle immediately above the opening of the mouth, so as to bound it superiorly like a median upper lip. It was separated from each lateral lip by a relatively deep furrow, and its inferior surface was continued behind into the premaxillary part of the palate. Paul Harting describes and figures in his fœtus a curved line on the neck, behind and above the fissure of the mouth, which he thinks may perhaps be the cicatrix of the last branchial cleft; no similar line was seen in my fœtus, although it was only about half the length of Harting's specimen. The mouth slit was 4 mm. long, and was bounded below by a distinct lower lip, and below the mandible a fold of skin projected downwards. The eyeball was relatively large, prominent, and dark coloured; it was covered by a prolongation of the integument, except at its centre, where a bit of cornea about 0·5 mm. wide was apparently exposed. There was no auricle to

the ear, and the external meatus was barely visible 6 mm. behind the eyeball. The length of the head in a straight line was 27 mm., and its zygomatic breadth was 16 mm.

The anterior limb was well marked, and the outline of the scapula and upper arm could be seen beneath the integument of the side of the body. The only parts of the limb which were free and enveloped by a common fold of skin were the forearm and hand. The length from the elbow to the free end of



X 2.

EXPLANATION OF FIG. 1.—Profile view of young fœtus, natural size; and front of face twice the size of nature.

the flipper was 15 mm. The flipper was directed with its borders forwards and backwards, and its surfaces inwards and outwards.

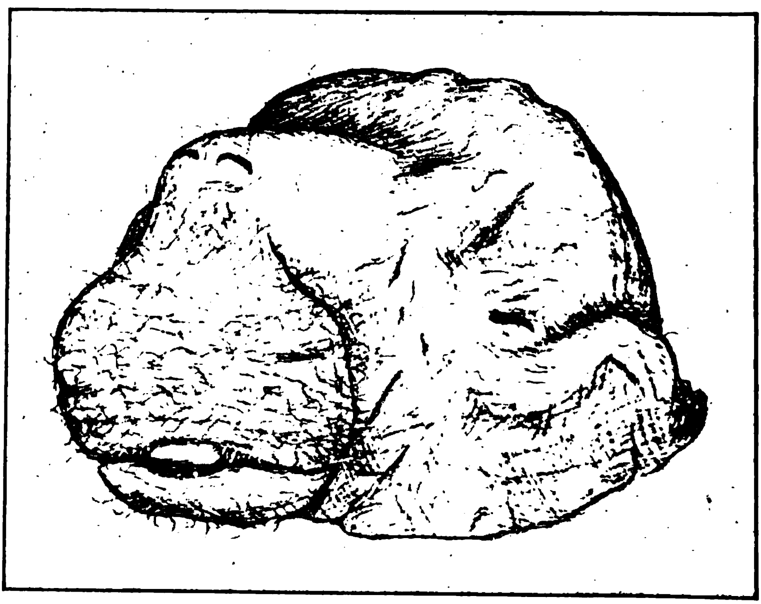
The anterior border of the manus was somewhat convex, whilst the posterior had a concavity at the interval between the tips of the 4th and 5th digits. The outlines of four digits could be seen distinctly through the thin integument, and in addition a short digit next the anterior or radial border was just visible. The 2nd, 3d, and 4th digits were relatively long, and were parallel and close together, but the 5th was inclined to the ulnar (posterior) border of the manus. The 4th was the longest digit, and reached the tip of the flipper; evidence could be seen

through the skin of transverse segmentation into phalanges in the four long digits.

The body was fusiform, and became much attenuated between the anal orifice and the tail. The greatest width of the horizontal tail was 25 mm.; its posterior margin was not notched in the middle, but had a slightly convex outline. The anus was 28 mm. in front of the mid-point of the tail. The penis projected from the surface of the abdomen 12 mm. in front of the anus, and was 5 mm. in length; the funis sprang from the wall of the abdomen 4 mm. in front of the root of the penis.

At this stage of development the subcutaneous fatty layer had not formed, so that the outlines of the ribs and vertebræ could be seen distinctly beneath the skin.

*b.*—The specimen received from Sir Wyville Thomson consisted of the head only, which had belonged to a fœtus intermediate



EXPLANATION OF FIG. 2.—Head of fœtal Dugong, drawn so as to give a view both of the muzzle and the side of the head. Natural size.

in size to the two fœtuses presented by Mr de Vis. The sex cannot be stated. The skin was dark brown, marked with wrinkles, and with very short silky hairs scattered on the vertex

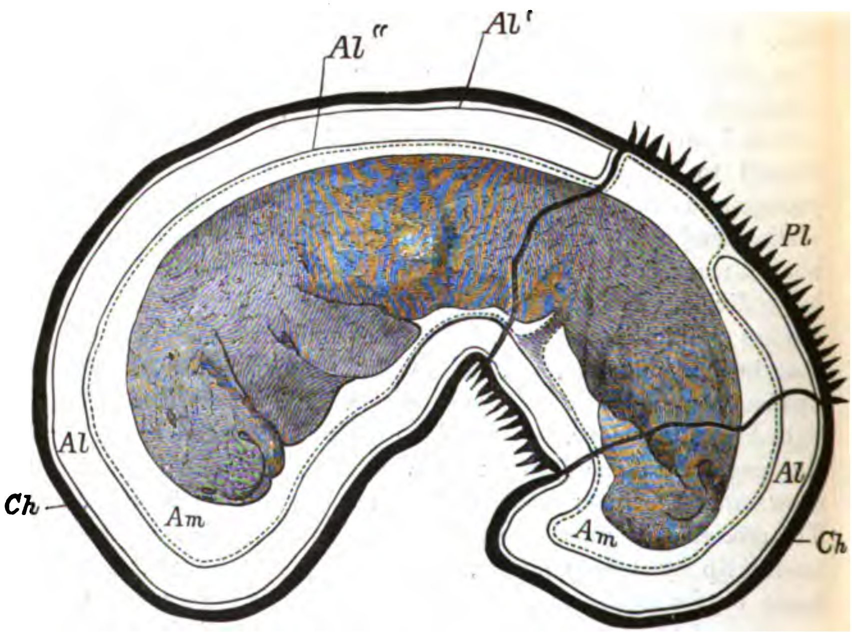
and sides of the head. The length from the front to the back of the head in a straight line was 105 mm., and from the nostrils to the mouth 45 mm. The greatest breadth between the zygomata was 75 mm. The distance from the nostril to the palpebral fissure was 39 mm.

Although the head was about four times bigger than that of the smallest fœtus, yet its profile outline corresponded in several particulars: for example, the frontal bulging was distinct, and in front of it was a hollow out of which a ridge emerged, at whose anterior end the nostrils were situated.

The nostrils were both behind and above the muzzle, so that, as in the youngest fœtus, they could be seen in the front view of the face. Each was crescentic and 4 mm. in transverse diameter. The plug-like valve seen in the older specimens was feebly developed. The muzzle formed a convex surface, and was bounded on each side by a well-defined fold of skin, which seemed to be proportionately more projecting than in the youngest fœtus. Its skin was transversely wrinkled, but the vertical and oblique fissures seen in the older specimens were not yet marked. It was covered with hairs, and at its lower edge divided into two lateral lips, between which a mesial process or mid-lip was seen, but it was much more concealed than in the youngest fœtus. None of the hairs on the lateral lips had assumed a bristle-like character. They were silky and light brown in colour, and could be traced backwards beyond the angle into the mouth; for a well-defined band of hairs grew from the inner surface of each cheek into that cavity. The process of the mid-lip was separated on each side from the lateral lip by a deep furrow, and the muco-cutaneous membrane on its under surface was continuous with the mucous covering of the premaxillary bones. The surface of the mid-lip was corrugated, but without hairs. Its anterior border was truncated and 12 mm. in transverse diameter. The antero-posterior diameter of the mouth cleft was 22 mm. The lower lip was a thick fold of skin, corrugated on the surface and studded with short silky hairs, not relatively so numerous as on the muzzle and upper lateral lips. The tongue was sessile; no teeth projected through the gum, and the mucous membrane covering the hard palate was smooth.

The border of the orbit was very prominent above, in front of and below the eyeball; between this border and the lateral fold of the muzzle the cheek was sunken. The transverse diameter of the palpebral fissure was only 5 mm., but a third eyelid was quite distinct at the inner angle. The external auditory meatus was scarcely visible to the naked eye 34 mm. behind the palpebral fissure.

*c.*—The largest fœtus of the Dugong was also a male, and gave the following measurements:—length along curve of head and back, 5 ft. 4 in. (162·6 cent.); from mid-point of tail to anus, 13 in.; from anus to orifice for penis, 5 in.; from orifice for penis




By permission of the Council of the Royal Society of Edinburgh, I am enabled to reproduce this figure.

FIGURE 3.—The fœtal Dugong inclosed by its membranes. *Ch*, chorion; *Pl*, zonary placenta; *Al*, sac of allantois; *Al'*, endochorionic layer of allantois; *Al''*, layer of allantois next the amnion; *Am*, sac of amnion.

to umbilical cord, 2 in. The tail was bent forwards, and concealed the anus and penis; the head was bent back towards the chest. The skin was smooth and of a dull yellowish-grey when

the fœtus was first taken out of its membranes, but after some time it became darker and browner. Scattered delicate silky hairs, from 5 to 10 mm. long, projected through the cuticle, and were more numerous on the head and body than on the tail and limbs; the mouths of the hair follicles were distinct, and the skin immediately around each follicle was paler than the skin generally. On the back of the fœtus the hairs were arranged in rows running from the head towards the tail, with considerable intervals between the rows and the hairs in each row. In these intervals fine dark spots were seen, which marked apparently the follicles of more delicate hairs, which had not yet pierced the skin. Delicate hairs also projected from the muzzle, but in the region of the upper lip stiff white bristles protruded in rows, and formed a moustache. The length of the head in a straight line was 260 mm., its greatest breadth was 165 mm.

The muzzle was characteristic. It was cleft below, and formed a well-marked lateral lip on each side, and in the cleft the mid-lip process was seen, which, when compared with the youngest fœtus, was not so patent, and was relatively much smaller than the two lateral lips, the skin of which was generally corrugated. A shallow mesial furrow extended up the muzzle for 34 mm. from the apex of the cleft, and was limited above by a transverse furrow. On each side of the mesial groove were two oblique furrows, one shallower than the other, which passed downwards and outwards into the lateral upper lip. The length of the mid-lip process was 17 mm., and its greatest breadth 28 mm. It was truncated at its free end, and flattened on the under surface, whilst the upper surface was somewhat convex; the posterior part of the upper surface was marked by an antero-posterior groove, 8 mm. long, in front of which was a transverse groove. The surfaces of the mid-process were without hairs and smooth, as if covered by a mucous membrane continuous above with that lining the upper lateral lips, and below with that of the premaxillary portion of the palate. The tuft-like arrangement of the papillæ seen in the adult male to be next described had not yet begun to form either on the mid-lip or adjoining palatal mucous membrane. The mouth was bounded below by a thick lower lip, which was truncated at its anterior free end; the antero-posterior diameter of the mouth-cleft was

68 mm. The tip of the sessile tongue was 20 mm. behind the truncated end of the upper lip. The skin below the lower lip bulged downwards, and numerous delicate hairs which formed a beard, projected both from this bulging and from the skin of the lower lip. No teeth could be either seen or felt projecting through the gums. The well-defined fold of skin, which gave so characteristic an appearance to the sides of the muzzle in the two youngest fœtuses, was not visible, either in this largest fœtus or in the adult. The development of the face bones and muscles and of the subcutaneous tissue had apparently caused it to unfold itself, and thrown it into the general integumentary covering of the region.

The nostrils were situated 8 mm. asunder at the upper part of the muzzle, 85 mm. above the cleft in the upper lip. Each was crescentic in shape, with a narrow fissure anteriorly, and the hollow of the crescent was occupied by a valve-like flap. The palpebral fissure was situated 66 mm. behind and above the angle of the mouth, and 85 mm. behind the nostril; the opening was only 8 mm. in its long axis, so that the eyeball was almost entirely concealed by the lids. The external auditory meatus was 78 mm. behind the palpebral fissure, and was no bigger than the head of a small pin.

The pectoral limb was paddle-shaped, and was free from the elbow to the tip. No nails were differentiated in the integument either of this or of the two youngest fœtuses; but the five digits could be felt through the skin. The length of the paddle was 194 mm. (7·6 inches), and its greatest breadth was 93 mm. (3·6 in.). It was directed obliquely backwards towards the tail, so that of its two surfaces the one was forwards and outwards, the other was backwards and inwards, whilst the radial border was forwards and downwards, and the ulnar backwards and upwards. The surfaces were flattened, and the posterior border was indented in the interval between the 4th and 5th digits.

The horizontal tail resembled in its general form the tail in the Cetacea. It measured 16 inches (407 mm.) between its tips; and as these projected a little behind the mid-point of the posterior border, the form of the border was on the whole concave, although there was no mesial notch, such as one sees in a

dolphin. The anal orifice was partly concealed in one of the deep transverse grooves which traversed the ventral surface of the fœtus. Through the circular opening of the sheath of the penis the glans protruded. The short umbilical cord had

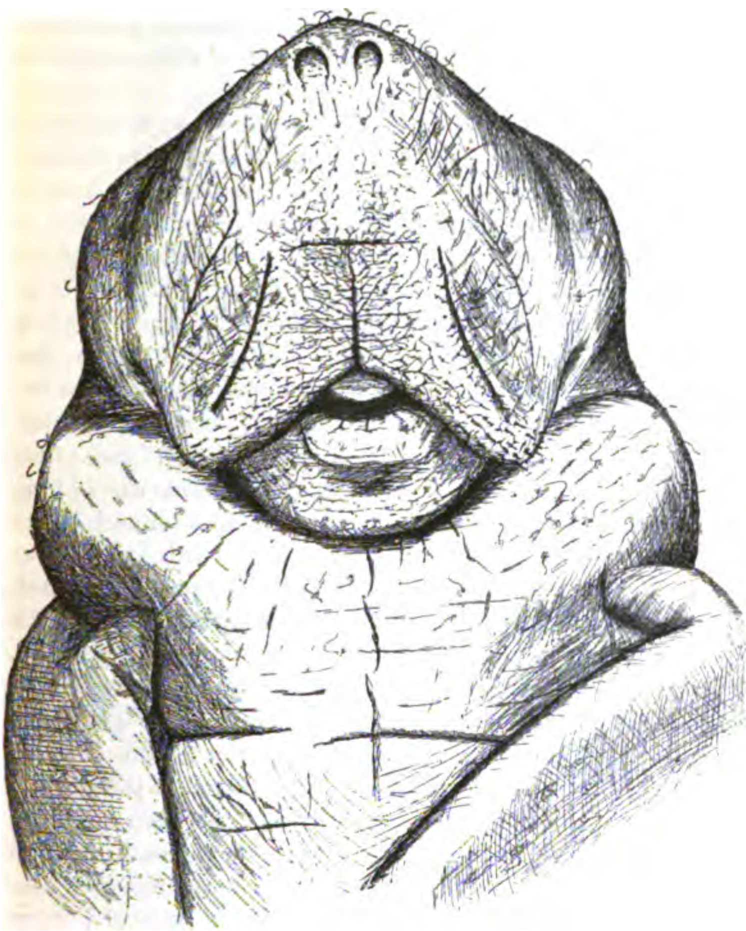


FIG. 4.—Front of face of largest fœtus of Dugong, reduced to one-half.

a strong base of attachment to the mid-line of the abdomen in front of the penis. I saw no signs of mammæ or nipples, either pectoral or abdominal.

*d.*—As I possess the head of an adult male Dugong from

Queensland, which had reached me preserved in dry salt, I have got Mr Rorie to make a drawing of the muzzle, which may be compared with those of the three fœtuses just described. In Sir Everard Home's figure[1] of this animal from a specimen from Java, 4 ft. 6 in. (68·6 cm.) long, the facial characters of a young female are represented. The series of figures will give a good idea of the changes which occur in the face at different periods of life and stages of development.

The drawing of my adult male shows the face from immediately in front of the nostrils to the fold of skin below the floor of the mouth. The muzzle was 13½ inches (343 mm.) from its upper limit to the lower part of the sub-mandibular fold of integument, and 8½ inches (216 mm.) to the opening of the mouth, and its greatest breadth was 7 inches (178 mm.). It had a vertical mesial furrow 4½ inches (115 mm.) long; 3½ inches on each side of which was a deep lateral furrow, continued downwards into the lateral upper lip. Between the two lateral lips a large middle lip or mesial process was situated. It was truncated in front, and measured 3 inches (77 mm.) from side to side, whilst its depth from before backwards was 1¾ inch. In the fissure which separated the middle lip from each lateral lip a powerful incisor tooth projected forwards, which was flattened from use at its free extremity, and measured 1 inch (26 mm.) across the worn end. The under surface of the middle lip was continuous with the palate in the premaxillary region. 40 mm. behind the truncated free border this surface was roughened with strong muco-cutaneous papillæ, from 3 to 5 mm. in length, and similar papillæ were seen on the mucous covering of the hard palate. The papillæ were arranged in tufts closely set together, but with a sufficient interval between adjoining tufts as to give to each somewhat of a circular outline. The tufts may be regarded as representing in a rudimentary condition the baleen plates which grow from the palatal mucous membrane of the whalebone whales. The integument of the middle lip was corrugated, and apparently devoid of hairs. The skin of the lateral lip was also corrugated and studded with strong brownish-yellow bristles, which varied in length from ¼ inch to 1 inch. Short bristle-like hairs were also situated on

[1] *Philosoph. Trans.*, vol. cx. pl. xxv., 1820.

the front of the muzzle and near the edges of the middle and lateral furrows, but in the upper part of the muzzle the hairs

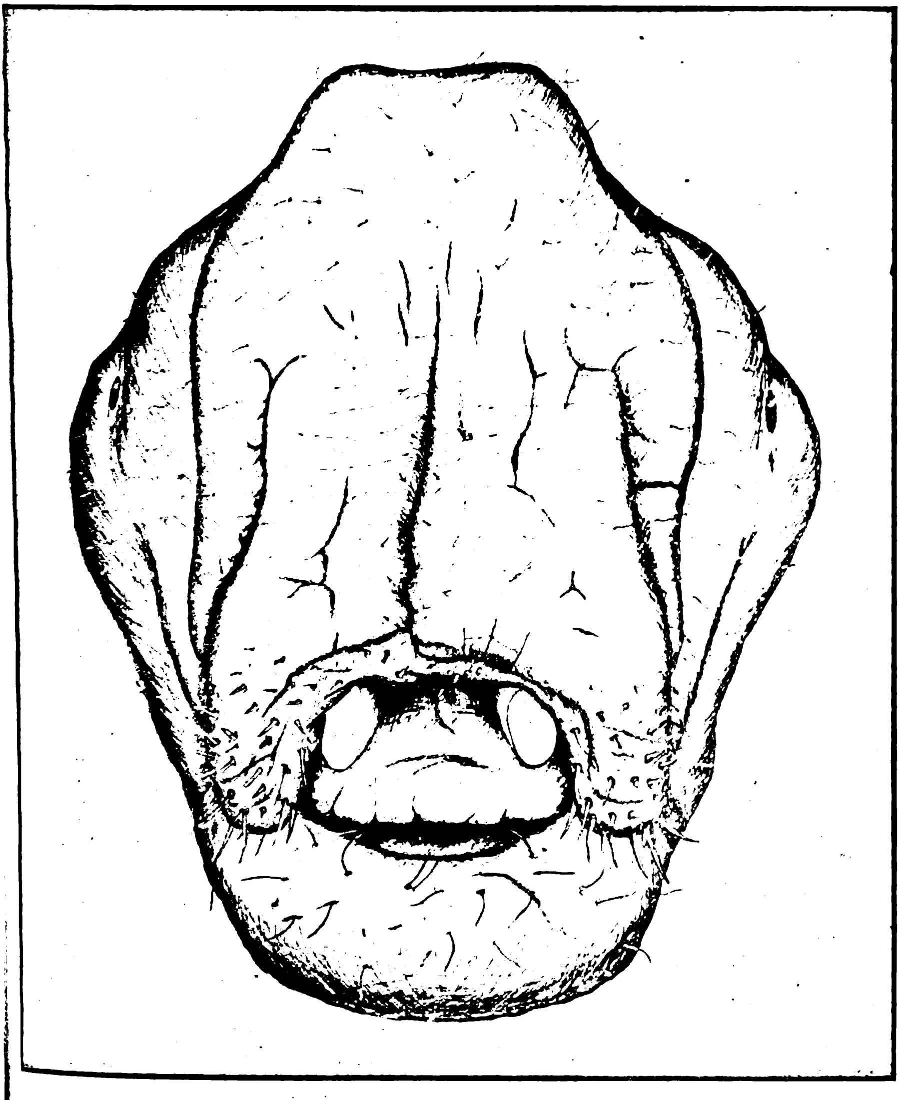


FIG. 5.—Front of face of fœtus of adult Dugong, reduced about one-half.

had lost their bristle-like character and were more silky. The lower lip and sub-mandibular fold had a number of bristly hairs,

some of which were nearly an inch long. The mouth-slit was short, and the distance from the angle to the centre of the lower lip was only 132 mm.

The upper surface of the lower lip, where it was in apposition with the under surface of the middle lip, was studded with short, strong, yellow bristles, similar to those already described in the lateral lips. All the lips were thick and massive and obviously mobile, a remark which especially applies to the upper lateral lips. They are doubtless employed by the animal in collecting the food previously to passing it into the mouth.

The nostrils were not visible in the front view of the muzzle, for the great growth of the premaxillary bones downwards and forwards in association with the large incisor teeth, had so elongated the muzzle that the anterior nares were elevated to the top of the fore part of the head, and had to be examined from the dorsal aspect. In this respect the adult differed from the three fœtuses in which the premaxillæ were only feebly developed. The nostrils were of the same shape as in the larger fœtuses, and with a similar plug-like valve, through the agency of which they could be completely closed when the animal was under water. The transverse diameter of each nostril was 1¼ inch (32 mm.), and the antero-posterior diameter was 1 inch (26 mm.). The width of the cutaneous septum between the two nostrils was 16 mm. The position of the nostrils would enable the animal to breathe with the minimum amount of the head exposed above the surface of the water. Behind the nostrils the top of the head was flattened; the skin was corrugated, and with scattered, short, silky hairs projecting from it.

The palpebral fissure was 177 mm. behind the nostril, and was 15 mm. wide, so that only a small part of the eyeball was uncovered; there were no eyelashes. The third eyelid could be seen without difficulty at the anterior angle of the palpebral fissure. The external auditory meatus was not visible, for the incisions through the skin made by the fishermen in cutting off the head were apparently in front of that opening. The length of the head in a straight line was 530 mm.; the greatest breadth was 310 mm.

Great discrepancies occur in books regarding the length of the Dugong. In various popular works on natural history the

animal is said to be 18 to 20 feet long. Sir T. Stamford Raffles states that a male taken at Singapore in June 1819 measured 8 feet 6 inches. Its skeleton and viscera were sent to England.[1] Two short tusks are described as projecting from the upper jaw, nearly covered by the upper lip. In all probability it was a well-grown animal. The head from Queensland, which I have above described and figured, was accompanied by the roughly cleaned skeleton, and it was obvious, both from the size and worn state of the incisor tusks, the absence of unossified epiphyses, and the remains of the penis attached to the pelvic bones, that the animal was an adult male. I thought, therefore, that the specimen would furnish me with data for computing the length of the animal. The spine, measured from the atlas to the mid-point of the tail, along the tips of the spinous processes, was 7 feet 6 inches; the length of the head from the top of the muzzle to the back of the occiput was 1 foot 8 inches, making together 9 feet 2 inches; if to this be added the distance (8½ inches) from the mouth to the top of the muzzle, the total length, measured from the mouth over the top of the head, and the curve of the vertebral spines to the mid-point of the tail, would be 9 feet 10½ inches. The spine was probably somewhat shorter than it would have been in the living animal, owing to the shrinking of the intervertebral discs from drying. But if due allowance is made for this, it is obvious that the length of this adult male did not exceed 10 feet, which is probably therefore about the length of the full-grown animal. I have already stated that the larger of the two male fœtal Dugongs which I removed from the uterus was 5 feet 4 inches in length, so that it had already reached *in utero* somewhat more than half the length of the adult animal.

In the Dugong, and doubtless also in other Sirenia, the fœtus, prior to its expulsion from the womb, as is well known to be the case also in the Cetacea, attains a magnitude in relation to the

[1] *Phil. Trans.*, vol. cx. p. 181, 1820. In the Museum of the Royal College of Surgeons of England are several skeletons of the Dugong, either young or incomplete, presented by Sir T. Stamford Raffles. An incomplete articulated skeleton is 6 feet 9 inches, but the lengths of the others are not given in the Osteological Catalogue. The articulated skeleton of a young female, the deciduous upper tusks of which had not been shed, from North Australia, presented by Lieut. Helpman, is 7 feet in length.

size of the adult much greater than is the case in terrestrial mammals. It is possible that the support given during gestation to the abdominal walls by the aqueous medium in which these animals live, may permit of a degree of enlargement of the uterus, and consequent increase in size of the fœtus, such as is not possible in animals which live on land.

(B.) *Manatus Senegalensis.*—When this fœtus reached me from the West Coast of Africa I found that the thoracic and abdominal viscera had been removed. In other respects the fœtus was uninjured, and its external characters could be studied. Other anatomists have also had the opportunity of examining the fœtal Manatee. In Buffon's *Natural History* a male fœtus from Guiana is described and figured[1] by Daubenton as "dix pouces et demi de longueur depuis le bout du museau jusqu'à l'extrémité de la queue et sept pouces de circonference à l'endroit le plus gros." C. F. Albers figures and gives an account[2] of a male fœtus preserved in the museum of the Physical Society of Bremen. Prof. Burt C. Wilder gives a brief description[3] of a fœtus, 2·3 inches long, from a tributary of the Amazon. The well-grown or adult animal has also been figured by Sir Everard Home,[4] A. von Humboldt,[5] H. Stannius,[6] Vrolik,[7] Murie,[8] Garrod,[9] and Agnes Crane.[10]

My specimen was a well-grown female fœtus, 864 mm. (2 feet

[1] *Histoire naturelle*, t. xiii. p. 425, pls. lvii.–lix.

[2] *Icones ad illustrandam anatomen comparatam; Fasc. secundus*, Leipzig, 1822. This fœtus was drawn and engraved by E. Pasquet and J. F. Schröter, and is evidently the specimen to which Wiegmann refers, p. 16, in his *Archiv für Naturgeschichte*, 1838, in his commentary on Humboldt's description of a large Manatee.

[3] *American Journal of Science and Arts*, vol. x., 1875, p. 105.

[4] *Phil. Trans.*, vol. 111, pl. xxvi., 1821. Specimen—a female from Jamaica.

[5] Wiegmann's *Archiv für Naturgeschichte*, 1838, pl. 1. A large female from the Orinoko river.

[6] *Beiträge zur Kenntniss der Amerikanischen Manatis*, Rostock, 1846.

[7] *Koninklijk Zoölogisch Genootschap*, Amsterdam, 1852. Specimen from America.

[8] *Trans. Zool. Soc.*, London, vol. viii., 1870. Specimen from Surinam. See also supplementary memoir in same *Trans.*, vol. xi. p. 19, on a female from British Guiana.

[9] *Trans. Zool. Soc.*, vol. x., 1875.

[10] *Proc. Zool. Soc.*, London, 1881, p. 457. Specimen from Trinidad. Dr Henry C. Chapman has described the anatomy of two young males of the American Manatee in the *Proc. Acad. Nat. Sciences*, Philadelphia, 1875, p. 452. The only figure which he gives is that of the brain.

10 inches) from the front of the muzzle to the end of the tail, measured along the top of the head and the back. The length of the head in a straight line was 165 mm., its greatest breadth was 134 mm. Sundry other measurements were as follows:—

| | mm. |
|---|---|
| From mid-point of tail to anus, | 300 |
| „ anus to orifice of vagina, | 33 |
| „ vagina to umbilical cord, | 155 |
| „ side of body to tip of flipper, | 148 |
| Greatest breadth of tail, | 193 |
| „ „ flipper, | 62 |
| Angle of mouth to palpebral fissure, | 48 |
| Mouth to nostril, | 40 |
| Nostril to palpebral fissure, | 50 |
| Palpebral fissure to external meatus, | 57 |

In writing this account of the external characters, I have had beside me Dr Murie's description and beautiful figures of the American Manatee which he dissected some years ago. The general form of the body of my specimen was necessarily affected by the removal of the viscera. The elongated form of the body, the constriction at the root of the tail, and the horizontal direction of the tail, with its remarkable shovel-like form, were recognised. There was no median notch at the tip of the margin of the tail, opposite the last caudal vertebra. Several transverse folds and creases, some of them of considerable depth, were seen in the integument, both dorsally and ventrally. No scale-like patches on the integument, such as Murie has described in his specimen, were visible. Silky hairs, the follicles of which were in most instances quite distinct, were scattered over the surface of the body, tail and flippers. The tegumentary envelope of the flipper inclosed upper arm, fore arm and manus. On the dorsal surface of the free end of each manus three well-defined nails were seen, and the place where a fourth had evidently been present. The nails belonged to the four finger digits and the comparatively rudimentary pollex had no nail. The fourth digit was the longest, and had the biggest nail.

The palpebral fissure was 5 mm. in width, and notwithstanding its small size, a distinct third eyelid could be seen at the

inner angle. The external auditory meatus was so small as to be seen with difficulty.

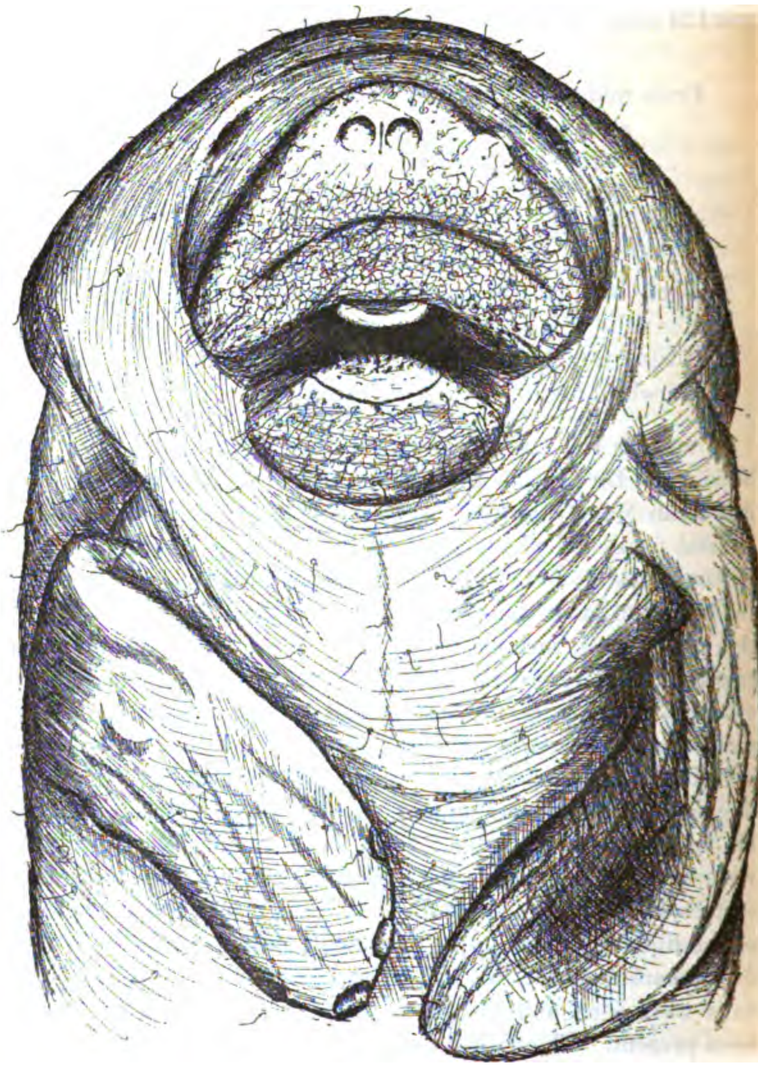


FIG. 6.—Muzzle and flippers of *Manatus senegalensis*, reduced one-half.

The muzzle was sharply differentiated above and at the sides by a vertical transverse fissure in the skin, which for a short dis-

tance on the left side was bridged by a cutaneous fold. This fissure was situated about half the distance between the palpebral fissure and the mouth. Seven mm. below it were seen the pair of crescentic nostrils, each with its valve-like plug. Thirty-three mm. below the septum of the nostrils was the mid-division of the upper lip, where it projected from between the two lateral lips. Each lateral lip was a thick mass of flexible integument, which bounded the side of the mouth. Near the margin these lips were studded with a small number of short, stiff bristles, but the rest of the tegumentary surface, and the muzzle above it, possessed numerous brown, silky hairs, and the inner surface of the lateral lips had a similar hairy covering.

The mesial process or mid-part of the upper lip was 17 mm. in diameter at its anterior truncated end. It was separated on each side from the lateral lip by a deep fissure. Only a few hairs grew from it in front, and its under surface was smooth and continuous with the mucous membrane covering the premaxillary region of the palate. The mucous covering of the hard palate was smooth, and did not show any definite arrangement of papillæ. The tip of the tongue was not sessile, but was partially movable, and its under surface had a distinct frænum. The crowns of several molar teeth in both upper and lower jaws had cut the gums. The lower lip was thick, flexible, and truncated at its free end. Bristly hairs were just visible projecting through its upper surface, but its under surface and sides had a considerable covering of silky hairs.

The pectoral limb was 169 mm. long from the side of the body to the tip. The radial border was convex; the ulnar border concavo-convex, but there was not a definite concavity in the interval between the 4th and 5th digits, as in the Dugong. No mammæ or nipples were recognised, either in the pectoral or abdominal regions.

The preceding description has brought out the features of resemblance and difference between the fœtal Dugong and Manatee, so far as the number of specimens and their stage of development permitted. A constant character in each specimen, both fœtal and adult, was the presence in the interval

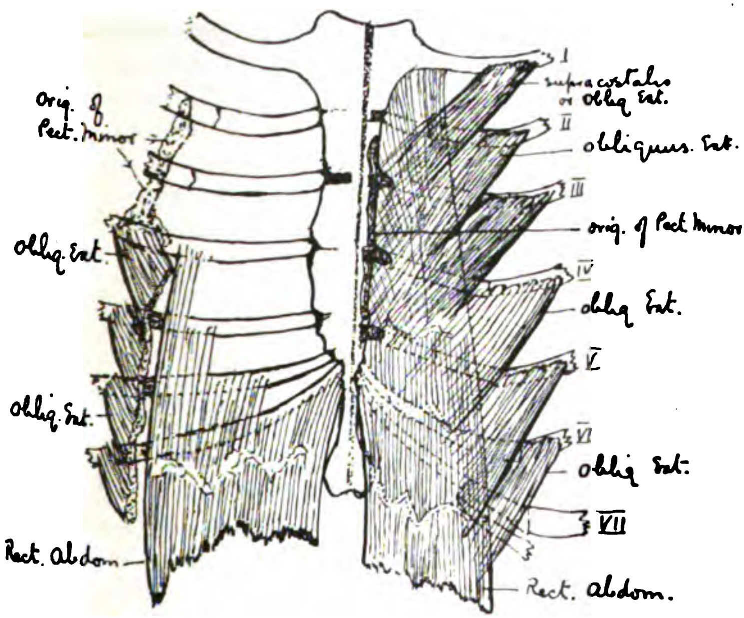
between the upper two lateral lips of a mesial process or mid-lip, which from being continuous with the premaxillary region of the palate may appropriately be called the premaxillary lip, and which is separated on each side by a deep furrow from the lateral lip. In these animals it would seem as if the portion of the upper lip arising from that part of the embryonic fronto-nasal process which W. His has named the processus globulares, and from which the premaxillary region of the hard palate also arises, does not blend with the lateral parts of the lips, which take their origin from the inner ends of the maxillary processes. The stage of separation between the mid-lip and the lateral lips, which in mammalia generally disappears by their fusion with each other, at a comparatively early period of development, remains permanent in the Sirenia, and constitutes a condition similar to that occasionally found in Man as an imperfect development, and known by the name of double hare-lip.

*(To be continued.)*

# NOTE ON THE SUPRACOSTALIS ANTERIOR. By ARTHUR KEITH, M.B.

THE supracostalis anterior, found in all cynomorphous Primates, is the digitation of the obliquus externus abdominis that takes its origin from the first rib. Its tendon splits on the tendon of origin of the rectus abdominis, and is inserted into the proximal pieces of the sternum. The digitations from the second, third, and fourth ribs are more frequently absent than present in the cynomorpha.

The digitations from the first four ribs would be best named the obliquus externus thoracis. It corresponds with the trans-




Anthropomorphous. Cynomorphous.

Figure illustrating the relationship of the *supracostalis* to the *obliquus externus abdominis.*

versus thoracis (triangularis sterni) on the inner side of the ribs. Both these muscles are rudimentary or absent in Man and the

Anthropoids. Rudiments of the obliquus externus thoracis rarely occur in those animals, the transmigration of the origin of the pectoralis minor from the sternum to the ribs having completely obliterated the muscle (see Figure). The obliquus externus thoracis is a respiratory muscle. The type of respiration in the cynomorpha is quite different from that of the Anthropoids and Man. This also accounts for its rudimentary nature in the highest Primates.

The rectus abdominis, over the first four intercostal spaces, has become obliterated in Man and the Anthropoids. The number of spaces is, however, variable. For instance, out of fifteen gibbons, the rectus reached cephalic-wards, as far as the third rib in two cases, as far as the fourth rib in six cases, and only as far as the fifth in seven cases. The point to which the rectus reaches has no connection with the species of the animal.

# NOTES ON A THEORY TO ACCOUNT FOR THE VARIOUS ARRANGEMENTS OF THE FLEXOR PROFUNDUS DIGITORUM IN THE HAND AND FOOT OF PRIMATES. By Arthur Keith, M.B. (Table.)

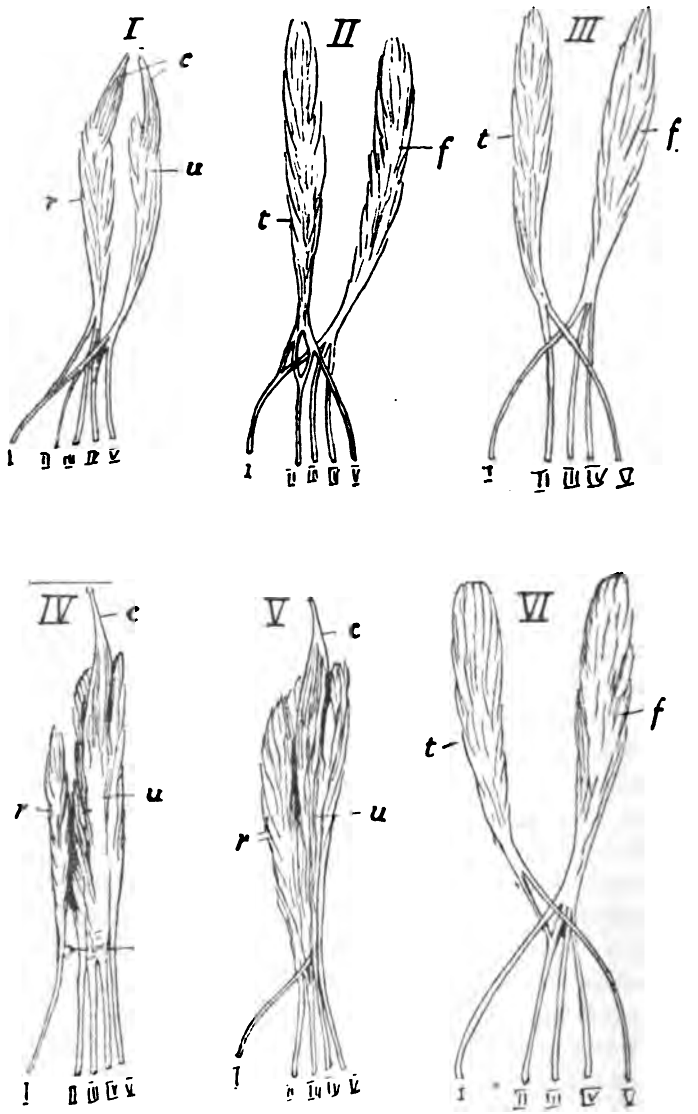
The linear segmentation of a muscle has little morphological value. The flexor profundus digitorum manus of a gibbon may be split up into seven pieces, or the belly of the muscle may be fused into a very slightly segmented mass. In all the Primates the various species show much individual variation in the segmentation of this muscle. But it is convenient to recognise the flexor profundus digitorum as being made up of a radial or tibial, and an ulnar or fibular segment. The radial segment is merely that part of the flexor profundus layer that lies towards the radial aspect of the forearm, the ulnar that which lies towards the ulnar aspect, and any line of distinction drawn between them is merely arbitrary.

There is reason to believe that the tendon for each digit of the flexor profundus digitorum is typically made up of both radial and ulnar elements, or tibial and fibular, as the case may be. Such a theory will account for the various arrangements of this muscle found in the Primates.

In the slow lemur, the tendon to the thumb is made up of radial and fibular elements (fig. 1). The flexor hallucis tendon in the same animal also contains tibial and fibular elements. The tendon to the hallux, in cynomorphous Primates, is composed of a fibular and tibial element (fig. 2). As is well known the tendons to the second, third, and fourth toes in Man are commonly composed of both tibial and fibular elements. In the slow lemur any of the digits may have a tendon derived from both elements (fig. 1).

One element may completely replace the other. A different arrangement was found in each of three slow lemurs, in the muscle of the arm as well as in the muscle of the leg. The composition of the tendon to the second, third, and fourth toes

TABLE.




**Explanation of Table.**—*r* and *u*, radial and ulnar borders; *t* and *f*, tibial and fibular borders; *c*, condylar heads.

is notoriously variable in Man, and the Gibbon in this respect resembles Man. Whether the tibial segment, or the fibular segment, wholly supplies the tendon to a digit, is a matter of no high morphological importance.

In Man and the Anthropoids, the tendon to the pollex, if it be present, is wholly derived from the radial element. It was absent in eight gorillas out of twelve; in ten chimpanzees out of twenty-five; it is always absent in the Orang; it is always present in the Gibbon, in which the pollex tendon may monopolise the radial element, but a part of the tendon to the forefinger may also arise with it (fig. 5).

In the cynomorphous Primates the ulnar element has completely substituted the radial element in the pollicial tendon (fig. 5).

The *cynomorphous* foot is principally a grasping organ, made up of two limbs—the hallux on one side and the four toes on the other. Each limb of this grasping organ receives a dual muscle-supply. The second and fifth toes, which are the lateral digits, and are of equal length, are supplied from the tibial element (diag. 2); the central toes—the third and fourth—are longer than the lateral digits, but of about equal length, and receive their tendons from the fibular element. The great toe has also a dual tendon. Thus the tibial as well as fibular segment acts upon both sides of the grasping organ. The fibular element, as a variety, has been found wanting in the hallucial tendon.

In the Anthropoids and Man, owing to the assumption of the upright position, the flexor profundus digitorum pedis has become not only a flexor of the toes, but, as it is necessary for upright progression, an elevator of the heel as well. The tendon of the fibular segment, owing to its passing under the ankle, nearer to the centre of the joint than the tibial tendon, is much more powerful as an elevator of the heel than the tibial segment. Hence in Man and the Anthropoids the complete substitution of the fibular element for the tibial element in the hallucial tendon.

The arrangements of the tendons of the flexor profundus pedis of the various members of the Catarrhini may be shortly expressed thus:—

*Cynomorpha.*—Tibial segment to I (part) : II : — : — : V.
„ Fibular segment to I (part) — : III : IV : —.

This is the typical arrangement of the grasping foot, and variations are not frequent.

*Gorilla and Chimpanzee.*—Tibial segment to — : II : — : — : V.
„ Fibular segment I : — : III:IV : —.

This arrangement occurred in twenty animals. In three other animals the second, third, or fourth toes received both tibial and fibular fibres.

*Orang.*—Tibial segment to — : II : — : — : V.
„ Fibular segment to — : —:III : IV : —.

This arrangement occurred in nine cases, and in seven remaining cases the third, or third and fourth, toes had a dual tendon-supply.

*Gibbon.*—Out of seventeen animals, no two possessed an arrangement exactly alike. As a rule, the tendons for the four inner toes are supplied chiefly from the fibular segment. The main feature of the various hylobatean arrangements is the substitution in part, or wholly, of the fibular instead of the tibial element in the second toe. In this connection it is interesting to notice that the second toe of the Gibbons is relatively longer than the corresponding digit in other Primates, and thus resembles Man. The Gibbon also resembles Man in having the tendon to this digit largely composed of fibular fibres.

The steadfast condition of these tendons, found in Cynomorpha, is evidently due to the arrangement being an adaptation to grasping. The cynomorphous grasp has been partially or completely abandoned by Man and the Anthropoids, and hence the arrangement of the tendons is a point which has fallen outside the pale of selection, and is therefore highly variable.

The layer of muscle forming the flexors of the metatarsi and metacarpi may also be regarded as being made up of a radial and an ulnar segment. If one assumes that each metacarpus or metatarsus may have typically a muscular supply from both segments, an explanation of the various arrangements of this layer in the arm and leg can be offered.

In the Cynomorpha the tendon of the supinator longus can frequently be traced to the first metacarpus. It appears to represent the radial segment of this layer. The ulnar segment is represented by the flexores carpi radialis and ulnaris. The flexor carpi radialis may be inserted on one, or two, or even three metacarpi.

In the leg the tibial segment of this layer is represented by the internal head of the gastrocnemius. The tibialis posticus reaches the bases of a variable number of metatarsi, and probably belongs to the fibular segment of this layer. The fibular segment also comprises the external head of the gastrocnemius, the soleus, and peroneus longus. The peroneus longus, according to this theory, is the fibular fibres of the metatarsal layer belonging to the first metatarsus. They are quite absent in the upper limb.

Traces of this mesial division into radial and ulnar segments are found in all the muscular layers of the forearm and leg, as well as in the osseous layer of those two parts. For instance, the extensor tendon to the third digit is made up, apparently always, from the two elements; hence the vinculum between the third and fourth tendons in the hand and foot. This vinculum is one of the most persistent features of the Primates, and appears to have no functional value.

CASE OF SINGLE UNILATERAL KIDNEY. By H. C. TWEEDY, M.D. Dubl., F.R.C.P. Irel., *Physician to Madam Steevens' Hospital, Dublin.*

THE patient in whom this rare condition was found was a woman aged 30, a widow—married thirteen years, and the mother of seven children. She was admitted to Steevens' Hospital on 27th July 1893, suffering from symptoms of portal obstruction, the result of cirrhosis of the liver, and ultimately died of acute peritonitis on the 9th January 1894.

At the autopsy the liver was found to be diminished in size, its capsule thickened, and the organ itself extensively cirrhosed. The portal vein and its tributaries were pervious and otherwise normal, as were also the gall bladder and bile ducts. The spleen was enlarged, dark in colour, and its capsule thickened.

The left kidney was greatly enlarged, though free from disease. The corresponding artery and vein were larger than usual, but normal in position. A point of special interest was the peculiar condition of one renal vein, which for a little part of its course was divided into two, and united again.

No trace of a kidney could be found on the right side, and a careful dissection revealed no renal vessels on the right side, nor was any trace of a ureter found on this side.

The measurements of the left kidney were as follows:—

Length = 13·5 cm.

Greatest breadth = 8 cm.

Breadth at the hilum 7·5 cm.

Thickness = 3·7 cm.

The suprarenal bodies were present on each side.

As Mr MacDonald Brown has written so recently and so fully in the *Journal of Anatomy and Physiology*[1] on this remarkable condition, it is not necessary to say much in comment on this case, but the following points seem worthy of notice:—

1. The condition was evidently congenital. No trace could

[1] Vol. xxviii. p. 196.

be found of a right renal artery or vein. There was also no ureter on the right side, and that belonging to the left kidney was[1] single, as well as being considerably wider in calibre than a normal ureter.

2. There were no indications during life that this condition was present, nor was the cause of death in any way connected with the absence of the right kidney.

3. In many of the cases described by English[2] and Continental[3] authors, anatomical defects were found in other organs on the affected side. In this case none such were discoverable.

4. The patient was a female, in whom the condition is more rarely found; the proportion of males being, according to Roberts, almost four to one. The left kidney is also more commonly absent than the right.

5. By a coincidence, in one of the recorded cases (Gubbin's),[4] the patient, as in the present instance, suffered from cirrhosis of the liver, with accompanying ascites.

[1] *Cf.* Roberts, *Urinary Diseases*, 1885.
[2] *Cf.* Greenfield, *Path. Soc. Trans.*, vol. xxviii. p. 164 ; Ogston, *Obst. Soc.*, Lond., vol. xxi. p. 57.
[3] *Cf.* Guttmann, *Archi. f. Pathologie*, Berlin, vol. xcii. pp. 187–191.
[4] *Brit. Med. Jour.*, June 1883, p. 115.

# THE DEVELOPMENT OF THE SKELETON OF THE LIMBS OF THE HORSE, WITH OBSERVATIONS ON POLYDACTYLY.

By J. C. EWART, M.D., F.R.S., *Regius Professor of Natural History, University of Edinburgh.* (PLATE XII.)

## PART II.

Embryo D—(*continued from page* 256).

BEFORE leaving the 35 cm. embryo (D), I shall refer further to the ossification of the os pedis and to the rudiments of the second and fourth digits.

(*a*) *The Os Pedis.*—In embryo C (50 mm.) all the long bones, with the exception of the phalanges, were undergoing ossification, while in embryo D (35 cm.) the phalanges were partly ossified. Except in the case of the terminal phalanx, true bone first made its appearance at or near the centre of the respective shafts or diaphyses, and gradually extended towards the extremities. But, as has already been shown to be the case in Man,[1] the ossification of the terminal phalanx in the Horse is peculiar. Instead of starting near the middle of the phalanx, it appears to gradually extend from the apex backwards. This difference in the mode of ossification is most probably due to the difference in the position of the subperiosteal bone. In the proximal phalanx (as indeed in all the other segments of the limb, the carpal region excepted) a ring of subperiosteal bone is first formed around the middle of the shaft. As this ring grows at both edges to form a tube, processes extend from its inner surface into the already calcified cartilage of the phalanx, and eventually convert it into true bone. In the terminal phalanx, instead of a ring of bone, there is first, as already pointed out, a subperiosteal bony cap investing the apex. As processes grow inwards from the bony tube surrounding the first phalanx, processes grow inwards from the bony cap investing the third, and hence of necessity the ossifica-

[1] Dixey, *Proc. Roy. Soc.* (Lond.), vol. xxxi. p. 65.

tion of the terminal phalanx, instead of extending from the centre to the extremities, extends from the apex to the base. This, though suggesting, does not necessarily imply that the tip of the terminal phalanx of the third digit corresponds to the middle of the first digit, or that the distal end of the third digit has been arrested in its development. The departure in the case of the third digit from the normal development is undoubtedly due to the presence of the bony cap, which is intimately correlated in the ungulates with the hoof, in other vertebrates with a nail or claw.

Dixey, in describing the ossification of the terminal phalanx says:—"The three processes of cartilage calcification, growth of subperiosteal intramembranous bone, and deposition of true bone in the shaft along the line of advance of the osteoblastic ingrowth, take the distal extremity of the shaft instead of its middle for their starting-point, and proceed in one uniform direction from tip to base."[1] This description will doubtless be found to apply to the third phalanx in the *Equidæ*.

In the horse the bony cap, apart from its remarkable wing-like expansions, reaches a considerable size before the osteoblastic irruption into the phalanx takes place. It is nearly relatively as extensive as the thimble-like bony investment permanently present in certain amphibians (*c*, fig. 26). When or where the osteoblastic ingrowths first invade the primary bone of the third phalanx, the available material does not allow of a definite answer.

In D the ossification of the phalanx is nearly co-extensive with the bony cap. But the third phalanx of D is especially interesting, because near its apex the true bone is being removed to make room for the semilunar sinus, which occupies a considerable part of the interior of the adult os pedis.

(*b*) *The Second and Fourth Digits.*—Since, and probably also before, Gegenbaur suggested that the presence of extra digits might in some cases be due to the existence of latent "germs" in the embryo, many have looked for vestiges of the phalanges of the second and fourth digits. But the quest, though doubtless often as keen as the relics if found would have been interesting, has hitherto been in vain. The terminal portions

[1] Dixey, *Proc. Roy. Soc.* (Lond.), vol. xxxi. p. 65.

("buttons") of the metacarpals and metatarsals ("splints") having been quite recently described as developing partly from epiphyses and partly from the shafts or diaphyses,[1] I started my investigations believing that there was no chance of either finding rudiments in the embryo, or vestiges in the adult, of the second and fourth digits. When, however, I discovered the nodule already referred to at the end of the second metacarpal of the 25 cm. embryo (B), the possibility of "germs" of these digits occasionally appearing and persisting for a time at once occurred to me. I did not, however, imagine that I would ever find fairly well formed phalanges, connected by joints to the ends of the splints, or that the "buttons" of the fully developed horse were the degenerated phalanges of the second and fourth digits.

To be in a position to understand the cartilages at the end of the metacarpals, it became necessary to learn something of the development of digits, and especially of their joints or articulations. In certain amphibians (*e.g.*, *Proteus*) the digital joints are extremely simple. Instead of a diarthrodial joint with a joint-cavity, a capsular ligament, lined with a synovial membrane, and articular cartilages, as in Man, there is simply a disc-shaped mass of cartilage lying between the calcified adjacent ends of the phalanges (*d*, fig. 26). Evidently the range of movement is very limited with a joint of this kind; nevertheless, it is extremely likely that in *Proteus* better formed joints never existed, *i.e.*, joints consisting merely of discs of cartilage inserted between the segments (phalanges) of the digits are, at least in certain amphibians, the highest form of joints yet arrived at. From the work of Dr Hepburn[2] and others, it appears that one of the first steps in the formation of the joints of the digits in the higher vertebrates consists in the division of the primitive rods of cartilage into segments by discs of indifferent cells. The segments eventually give rise to phalanges, while the discs seem to be especially concerned in forming the various parts of the joint, such as the articular cartilages, the capsule, and the delicate membrane lining the joint-cavity. These articular discs probably correspond to the discs in *Proteus*, and represent one of the stages in the evolution of joints.

[1] Struthers, *Jour. of Anat. and Physiol.*, vol. xxviii. p. 51, 1893.

[2] *Jour. of Anat. and Physiol.*, vol. xxiii. p. 507.

This information having been acquired, I proceeded to study anew the digits of embryos A, B, and C. In A (the 20 mm. embryo) I failed to observe clear indication of joints, but noticed at the pointed curved end of the fourth digit two lines running across the cartilage, which seemed to indicate that it was undergoing segmentation. On studying further the manus of embryo B, I had no longer any doubt that an incomplete joint had existed between the nodule previously removed and the rounded end of the second metacarpal. This nodule, which was only about ·3 mm. in length, is represented in figure 27. The somewhat concave surface at the proximal end was partially coated with cells, which probably represented an articular disc. The end of the metacarpal was smooth and rounded, but entirely made up of cartilage cells.

Although it was impossible to determine whether the cartilage forming the axis of the nodule had undergone segmentation, I have now no doubt that it represents all the phalanges of the second digit,—not, as I at first believed, the proximal phalanx only. In the 50 mm. embryo (C) nothing very definite could be made out as to the second and fourth digits. With the exception of the fourth digit of the left manus, those available for re-examination were so completely invested with cells and fibres that little could be seen; and even in the comparatively uninvested fourth digit it was only possible to note indistinct lines, which seemed to occupy the position of phalangeal joints. In this embryo I hoped to find articular discs, but neither in this nor in any other embryo examined have true discs been observed.[1] It is quite possible that true discs are never developed, even although, as will appear later, there are in some cases fairly well developed joints. This question, however, can only be solved when more material is available.

Coming now to the 35 cm. embryo (D), we find the second and fourth digits, at what further investigations may prove to be (save in very exceptional cases) the climax in their development. The second and fourth digits of the manus are

[1] Perhaps the few cells at the proximal end of the rudimentary digit from embryo B may represent an articular disc. If it is impossible for a joint to develop without discs, it must be taken for granted that they exist, or at least that isolated cells capable of playing the part of a disc are invariably present.

represented in figures 28 and 29. At the outset, each of the metacarpals II. and IV. seemed to be terminated by an elongated epiphysis. It was only after prolonged maceration and teasing in cedarwood oil that the presence of rudimentary digits was revealed. First of all, as the investing tissues were removed—as the digit was unwrapped—the epiphysis (*e*, fig. 28) became evident; next, the presence of a joint (*j*) beyond the epiphysis; and finally, the characteristic curved terminal phalanx (3, fig. 28), with its pointed tip invested by a small well moulded cap (fig. 28$^a$). The metacarpo-phalangeal joint was evidently functional, but there was extremely little evidence of movement between the second and third phalanges, while the joint between the first and second was only represented by a narrow cleft. Longitudinal sections confirmed these views as to the joints. The metacarpo-phalangeal was so complete that the epiphysis of the metacarpal, with part of the shaft attached, was often found in the sections separated from the phalanges. The joint between the second and third phalanges was evidently less developed, while that between the first and second was only represented by an indistinct fissure extending about half way across the cartilage. The fourth digit (fig. 29) only differed from the second in being more slender, and in having a less pointed and less curved terminal phalanx. All three phalanges consisted entirely of cartilage, and there was nothing peculiar in the arrangement of the cells. The epiphysis (*e*), on the other hand, had its lower end slightly rounded, and from the arrangement of the cells in rows it was evident that calcification had already set in. Further evidence of the presence of a digit containing representatives of all three phalanges was afforded by the cap investing the tip of the digit. This cap (fig. 28$^a$), which was easily removed, was entirely composed of cells, the nature of which could not well be determined. Whether this cellular cap represents the bony cap which, as already explained, invests the terminal phalanx of the third digit, or whether, as seems more probable, it represents a rudiment of the hoof, it is difficult to determine. From what has been said above, there is no escape from the conclusion that in a 35 cm. embryo the second and fourth digits are present, and though extremely small, are far better developed than could

have been anticipated before the investing tissues were removed. The condition of these digits in older embryos will be considered later; but before leaving embryo D, it is well worth noting that we have already evidence of degeneration, more especially in the all but complete union of the first and second phalanges. I draw attention to this now, because when I come to describe a case of polydactyly I shall have especially to point out that though the second phalanx of the second digit is relatively large (over 2 cm. in length), the joint between it and the first phalanx has all but completely disappeared.

As formerly mentioned, and as indicated in figure 30, the second and fourth metacarpals were well ossified. The cartilage at the proximal end of each is relatively large, measuring nearly 5 mm., while the cartilage at the distal end, destined to become eventually a true epiphysis,[1] though well formed, measured in each case under 2 mm. Although not very evident in the figures, the shafts of metacarpals II. and IV. were bent, and applied to the inner and outer aspects respectively of the large third metacarpal.[2]

Before proceeding to consider a larger embryo, it may be well to point out that in D (the 35 cm. embryo) we have (when the relative lengths of the humerus, radius, &c., are considered) undoubtedly reached the horse stage. We have, in fact, in embryo D very nearly the same amount of specialisation in the skeleton of the fore-limb that obtains in our best bred horses. Evidence of this can be satisfactorily obtained by referring to Tables I., II., III., IV., and V.

In Table I. the actual size of the chief segments of the limbs of D and other embryos is given, also the sizes of the bones in various recent *Equidæ*, and in certain extinct forms. In addi-

[1] So far as regards this paper I shall consider "epiphysis" to mean a separate ossification at the end of a long bone. As the cartilages at the proximal ends of the metacarpals never undergo independent ossification—the ossification simply extends into them from their respective shafts—they are not, according to this view, true epiphyses. Perhaps true or bony epiphyses are only formed where more resistance is required than can be given by cartilage during the growth in the length of the bone as the adult form is reached.

[2] It is worth noting that the second and fourth metacarpals are, compared with those of Embryo E, fig. 32, relatively short. In all probability these metacarpals are short in some breeds and long in others.

tion, Table I. indicates (in the case of the smaller embryos only approximately) the lengths the radius, the third metacarpal, and the three phalanges would have if they bore the same relation to their respective humeri as the corresponding structures do to the humerus in the highly specialized racehorse "Hermit."[1] For example, the radius of embryo D being 6·15 cm., and the humerus measuring 5·50 cm., these bones stand, as the table shows, in exactly the same relation to each other as do the corresponding bones in "Hermit." But not only do we find the radius relatively as long in embryo D as in "Hermit," we find the third metacarpal actually relatively longer. Taking "Hermit" as a standard, the length of the third metacarpal in D should be 4·15 cm., but its actual length is ·45 cm. above this. The three phalanges, to be of the same relative size as in "Hermit," should be 3·20 cm.; their actual size I made out to be 3·15 cm. Hence all the segments of the fore-limb of D are relatively as nearly as possible of the same size as the corresponding segments in "Hermit," with the exception of the third metacarpal.

Further evidence of this is afforded by the other tables. In Table II. it will be noted that while in "Hermit" the radio-humeral index is 111·94, in D it is 111·81, *i.e.*, only a difference of ·13. Table III. indicates that while in "Hermit" the relation of the third metacarpal to the humerus is represented by 76·11, in D it is 83·63; Table IV. shows that while 58·20 indicates the relation of the three phalanges to the humerus in "Hermit," 57·27 is the relation in embryo D; while Table V. shows that the first phalanx in D is 26·36, in "Hermit" it is 25·37. In other words, while the radius is relatively the same length, the third metacarpal is relatively somewhat longer in D than in "Hermit": whether the increase in the length of the third metacarpal is an indication of higher specialisation will be considered later.

Having given reasons for coming to the conclusion that when the length of the various segments of the fore-limb is considered, the horse stage is arrived at when the embryo reaches a length of about 35 cm., the question may now be asked, What evidence is afforded by the horse in favour of the recapitulation theory—

[1] "Hermit" won the Derby in 1867, and was 15·2½ hands—62½ inches high.

that animals repeat their phylogeny or ancestral history during their ontogeny or development? To put it another way, Is there any evidence that a horse, during its development, "climbs its own ancestral tree"? In describing embryos A, B, and C, I pointed out in what respects they agreed with *Hyracotherium* and *Mesohippus*, and I have indicated that D, though to all intents and purposes a horse, in some respects suggests *Hipparion*. But while there is a resemblance which I think is far from meaningless between the skeletal elements of the arm and forearm of very small horse embryos and certain remote "fossil horses," and a more complete resemblance between larger embryos and the less remote *Hipparion*, I do not think that one would be justified in saying that either of the embryos A, B, or C reproduced in their limbs the characters of any of their supposed ancestors. The skeleton of the limb when taken as a whole in no case agrees with any extinct form yet described; from the first there is evidence of adaptive rather than ancestral characters. Much, however, depends on what is implied by recapitulation. Perfect recapitulation would mean that when a horse reaches the size of a fox it should present the characters of *Hyracotherium*, when about the size of a Newfoundland dog the characters of *Mesohippus*, and so on. No one, however, insists on an exact recapitulation; even those who push this hypothesis furthest make some reservations.

Evidently if the reservations made on the plea of abbreviation in development, &c., are almost unlimited, a very remote resemblance in an embryo to a supposed ancestor might be considered sufficient evidence of recapitulation. For example, because the humerus and radius of embryo C resemble the corresponding structures in *Mesohippus*, it might be held by some that a horse embryo when 50 cm. in length reproduced the *Mesohippus* stage in its phylogeny. There must, however, be some limit to the use of the word recapitulation. Unless it implies more than the resemblances found between any given forms which have descended from the same ancestors, it is practically meaningless. All embryo vertebrates are more or less alike at first, but the further they proceed along their special lines of development the more they come to differ from each other. Recapitulation, if it means anything at all, must be

held to mean that, say in the case of the horse, the embryo should after a time not only resemble the unknown embryos of its extinct ancestors, but that it should resemble the fully-developed ancestors. This implies that during its ontogeny the horse should not only advance in a zigzag fashion along the trunk of the animal tree, but also when it reached its own particular branch that it should during its onward course make deflections in the direction of *Hyracotherium*, *Mesohippus*, &c., until having, at a respectful distance, done hurried homage to its ancestors, it at last reaches its final goal, and presents its true characters. If the recapitulation theory implies marching and counter-marching during development, the horse, as far as its ontogeny is known, gives little support to it. It is impossible, with any degree of accuracy, either to speak of a *Hyracotherium* or a *Mesohippus* stage, or even of a *Hipparion* stage. If, on the other hand, all that is meant by recapitulation is that the developmental record of any given form is represented by a series of zigzags or curves instead of by a straight line, the horse may be claimed as supporting it. As is to be expected in forms which have evidently descended from the same ancestors, there is a certain amount of agreement between horse embryos and the so-called fossil horses; and were it possible to know the development of these extinct forms, the points of agreement would be doubtless increased. Further, as might also have been expected, the points of agreement become more numerous and more evident as *Hipparion*—a not very ancient form—is reached. So much is this the case, now that we know the second and fourth digits are for a time fairly well developed, we might speak of a *Hipparion* stage in the ontogeny of the horse. To admit that the horse, before assuming its own specific characters, makes, as it were, a deflection towards the not very ancient form *Hipparion*, is hardly going far enough to justify the assertion that the horse during its development assumes, one after another, the characters of its ancestors, or, in other words, except in a most limited sense, "climbs its own ancestral tree."

To sum up, it may be said that while a horse embryo never sufficiently resembles any of the "fossil horses" to afford evidence in support of unrestricted recapitulation, it sufficiently

resembles them to justify the assumption that they are genetically related.[1]

### (5) Embryo E.

The limbs of the horse being extremely specialised structures, I expected to find that the adult characters would be late in appearing, that, *e.g.*, at birth the radius would have about the same relative size as in *Hipparion*, and that the third metacarpal and the phalanges would stand in about the same relation to the humerus as in the ass or zebra. From what has been said of embryo D, it is evident that, if the length of the bones of the fore-limb be taken as a standard, the adult form is all but completely assumed when the embryo is from 30 to 40 cm. in length. This being the case, in studying the limbs of larger embryos we shall have to consider not so much their development as their growth and ossification, the time at which the peculiarities of special breeds make their appearance, and the variations in the lengths of the radius, the third metacarpal and the phalanges.

Bearing these factors in mind, I shall next describe the fore-limb from an embryo which measured 50 cm. in length.[2] The limbs of this embryo (E), though considerably larger, very closely resembled those of embryo D. The skeleton of the left fore-limb is represented natural size in figure 31. In comparing the limbs of E and D, one notices especially that in E the chief bones are more massive and better moulded; that the lower end of the ulna is, if anything, better developed, and that the second and fourth metacarpals are considerably longer than in D. When compared with "Hermit," the fore-limb of E differs chiefly in the small size of the muscular processes, the incompleteness in the ossification, the completeness and independence of the ulna, and the wedge-like shape of the terminal phalanx.

On referring to Table I. it will be observed that in E, as in D, the radius has the same relation to the humerus as in "Hermit," while the third metacarpal and the united phalanges are relatively longer than in "Hermit." Embryo E agrees

[1] For an interesting paper on "The Recapitulation Theory" by Hurst, see *Natural Science*, vol. 2, No. 13, 1893.

[2] This was said to be a six months' embryo.

with the ass and *Hipparion* in having the third metacarpal relatively longer, but differs from these forms in having the phalanges also longer.

Table II. shows that the radial index—the humerus being 100—is 111·84 (in "Hermit" it is 111·94). From Table III. the metacarpal is seen to be in E 88·15—the humerus being 100 (in "Hermit" it is 76·11). Table IV. shows that the three phalanges in E are together 65·72—in "Hermit" they are only 58·20; while Table V. indicates that the first phalanx is also relatively longer than in "Hermit."

The greater relative length, when compared with "Hermit," of the third metacarpal in D and E demands some explanation. Evidently the greater relative length may be due to several causes. It may be due (*a*) to the humerus being relatively shorter than in the adult; (*b*) to embryos D and E belonging to a different breed of horses than "Hermit"; (*c*) to recapitulation—the supposition being that the horse has during its evolution passed through a stage characterised by a relatively longer third metacarpal than exists in the well-bred horses of to-day; or (*d*) to the third metacarpal growing at a greater rate in the embryo than the humerus and radius. A consideration of the measurements of embryos and of adult horses gives no support whatever to the supposition that the humerus is relatively shorter in the embryo than in the adult,[1] and though in *Hipparion* and the ass the third metacarpal may be relatively longer than in "Hermit," it does not follow that recent horses have descended from a variety characterised by a long third metacarpal. Everything considered, it seems most probable that the greater relative length of the third metacarpal in D and E is due either to their belonging to a larger breed of horses than "Hermit," or to the third metacarpal in D and E having begun to grow at a quicker rate than the other long bones. It may even be due to a combina-

[1] The humerus is relatively long in small embryos, and it is, when the height is considered, relatively longer in "Egil" (a 38-inch Shetland pony—skeleton preserved in Anatomical Department) than in "Hermit." In "Hermit," a 62½-inch horse, the humerus is 33·50 cm. If bearing the same relation to the height, it should be 20·36 cm. in "Egil." But the actual length of the humerus in "Egil" is 22·40 cm., *i.e.*, it is relatively longer than in "Hermit," when the height is considered, by 2·04 cm. In the 88 cm. embryo (I) the humerus is, as in "Egil," over 2 cm. relatively longer than in "Eclipse."

tion of these causes. The radius and third metacarpal in the 38-inch pony "Egil" being relatively as nearly as possible the same length as in "Hermit," it might have been concluded that the same or almost the same relations between the various segments of the fore-limb would be found in all breeds of horses; and further, that when the various segments assumed the same proportions in the embryo as they have in the adult, they would retain these proportions, at least until birth. Neither of these assumptions, however, is warranted by the facts about to be stated.[1] That the third metacarpal is not always of the same relative length, even in race-horses, as in "Hermit" is readily proved. "Hermit" was described in 1867 as "short from the knee and hock to the ground."[2] In support of this view I may mention that in the famous horse "Eclipse" (which was about the same height as "Hermit") and in "Orlando"[3] the third metacarpal was slightly longer than in "Hermit" (Table I.)—in "Orlando," though the humerus was 1·50 cm. shorter, the radius was 1 cm., and the third metacarpal 1·30 cm., longer. Turning to hunters, and to certain Irish and Canadian breeds, the metacarpal region is sometimes relatively extremely long. Hence in D and E it is possible that the metacarpal is relatively long because they belong to a long-legged breed of horses. But while the greater length of the metacarpal may be in some cases due to the embryo belonging to a special breed of horses, in the majority of cases, as may be gathered from Table III., the increase in length is undoubtedly due to excessive growth during the last six months of fœtal life of the metacarpal and metatarsal regions.[4] If, therefore, the greater length of the third metacarpal in D and

[1] Neither of them would be entertained for a moment by experts in horses, for it is a matter of common knowledge that some horses are relatively long from the "knee" downwards, and that in the foal the legs are relatively surprisingly long. I have heard it stated that the cannon bone (third metacarpal) has reached its maximum length at birth, and that its great length was "designed" with a view to enabling the foal readily to reach the nourishment on which for a time its existence wholly depends.

[2] *Illustrated London News*, 1867. "Hermit" won the Derby this year.

[3] "Orlando," which died the year after "Hermit" won the Derby, was a well-bred horse belonging to Her Majesty the Queen; the skeleton is preserved in the Roy. Coll. of Surgeons' Museum, London.

[4] The necessity for relatively long legs at the outset is obvious enough. From the time the existence of the horse ("fossil" or recent) in any given area

E is due either to their belonging to a larger breed of horses than "Hermit," or to the fact that in horse embryos this bone grows more rapidly than either the humerus or the radius, the interesting conclusion is forced upon us, that not only has an embryo when about 35 cm. in length assumed the characters of a horse (the skeleton of the fore-limb being taken as a standard), but further, that it even at this stage begins to acquire secondary and adaptive characters. Mr Darwin could, in many cases, tell the breed of pigeons only a few hours old, and in the case of the short-faced tumbler he found the same proportions of the various parts as in the adult.[1] In the same way it may be found that in the case of horses the peculiarities of the breed appear at a comparatively early stage in their development, which—if recent horses are related to the ancient "fossil horses," or even to *Hipparion*—implies marked abbreviation in their ontogeny.

Very little requires to be said as to the individual parts of the skeleton of the fore-limb in embryo E. The humerus (*h*, fig. 31) measures along the outer aspect 7·60 cm. The curving of the shaft, its thickness and the extent of the ossification are sufficiently indicated in the figure (31). The epiphyses, though still quite unossified, very closely resemble the upper and lower ends of the adult humerus. In both epiphyses the cartilage was more altered than in embryo D, and in the vicinity of the ossifying shaft the cells were enlarged and arranged in rows; elsewhere they presented the usual appearance. Compared with the adult, the space for the olecranon process was relatively wider. In a longitudinal section a

mainly depended on its fleetness, the foals born with long legs would have, other things being equal, the best chance of surviving in a wild herd. It is stated the stallions of a herd sometimes compel, or do their utmost to compel, the mares to forsake their foals. But apart from this habit, supposing it existed and operated seriously against slow-moving foals, the length of the legs up to a certain point, and the development of the leg-muscles, would be of the greatest possible advantage, especially in periods of panic, and when the dams and their foals straggled some distance from the herd. It might be said that with short limbs a high rate of speed can be accomplished. On the other hand, it has to be considered that the horse has not the advantage of being able to progress like a hare or a dog when quite young and in a different fashion afterwards; from the first its movements are those of a horse, and this being the case the rate must be intimately related to the length of the limbs.

[1] *Origin of Species*, 6th edition, page 392.

distinct medullary cavity filled with marrow occupied a little over one-third the length of the shaft, and the cartilage bone at each end presented quite a different appearance from the dense outer part of the shaft, derived directly from the periosteum. The radius (8·50 cm. in length, *r*, fig. 31) was relatively wider at its upper end, and more rounded posteriorly than in the adult. The proximal epiphysis presented a smooth surface posteriorly, of the same relative size as in the adult, for articulating with the epiphysis of the ulna, while the distal epiphysis, relatively wider than in D, was bevelled[1] externally for the lower expanded end of the ulna (figs. 31, 32), and presented special surfaces for articulating with the scaphoid and semi-lunar. The ulna (10·50 cm. in length, *u*, fig. 31) differed mainly from that of the adult in having the olecranon process and upper part of the shaft relatively thicker, and in having the most distal portion still free and distinct from the radius. The shaft, though complete,[2] was relatively more slender than in the skeleton of the large Spanish ass in the Royal College of Surgeons' Museum, London—only in this recent member of the *Equidæ* have I seen a complete ulna. In E only the most distal portion (*s′*, *s″*, fig. 31, about 9 mm.) of the shaft of the ulna remained unossified. The carpals, though still cartilaginous, very closely resembled those of the adult. The cuneiform (ulnare) articulated with the ulna—not at all with the radius. There was a very small trapezium (*c*, 1) lying posteriorly across the joint between the trapezoid and second metacarpal. The cuneiform and unciform (*c*, 4 and 5) together measured 1·25 cm. along their outer surfaces, which makes the carpal region relatively longer than in "Hermit" by ·17 mm.

The third metacarpal (III. fig. 31) measures 6·7 cm. and is relatively ·92 mm. longer than in "Hermit." The shaft, when viewed from either side, is seen to be more concave (fig. 31)

[1] It would be more accurate to say that the lower end of the radius had grown outwards without displacing the most distal part of the ulna, see figures 31 and 32.

[2] Riazheff in a paper, for a copy of which I am indebted to Rosenberg, rightly points out that, notwithstanding recent statements to the contrary, the distal end of the ulna persists in the embryo. I shall later show that it persists in the adult. For an abstract of Riazheff's paper, and for much help with the literature of the subject in hand, I am indebted to Mr Webster, University Librarian.

from above downwards than in the adult, but it has relatively the same width. The cartilages at the extremities had increased in size, but the distal cartilage, though similar in form to the epiphysis in the foal, had not begun to ossify. The phalanges, taken together, are 5 cm. in length. If of the same relative length as in "Hermit" they would measure 4·39 cm. The humerus taken at 100, the united phalanges in E would be 65·78; in "Hermit" they would only be 58·20 (Table IV.).

The first phalanx is relatively the longest, being 26·31 (the humerus = 100), while in "Hermit" it is 25·37, and in "Egil" 25·44 (Table V.). As figures 31 and 32 show, only about one-third of the first phalanx has been ossified.

The second phalanx (2, fig. 31), about half the length of the first, is very slightly ossified. In this case the irruption has evidently taken place from behind to form an irregular nodule which on section is seen to lie far removed from the anterior surface.

The third phalanx chiefly differs from embryo D externally in having a larger cap. The cap in front is extremely porous, while behind it is smooth and compact except near the apices of the wings, where pores are numerous. When viewed from behind, distinct notches (fig. 32*a*) occur where the plantar vessels enter.

In longitudinal sections a considerable area is seen to be occupied mainly by fat-cells, and under this there is a distinct space —the first clear indication of the semilunar sinus. The soft area occupied by fat-cells, osteoclasts, &c., seems to correspond to the most anterior portion of the phalanx proper. This area in all probability corresponds to the medullary cavity of an ordinary long bone. The basal portion of the third phalanx is partly calcified, but there is not yet any indication of an independent ossific centre for a proximal epiphysis.

The second and fourth metacarpals, and the vestiges of their respective phalanges in embryo E, have still to be considered.

The second metacarpal, including the distal epiphysis, measures 5·25 cm., the fourth 5·20 cm.—in each case the epiphysis (*e*, fig. 33) is slightly over 1 mm. in length. The unossified upper ends (*c'*) of the metacarpals are very much larger than the epiphyses— they nearly equal in length the unossified upper part of the third metacarpal. The phalanges of the second and fourth

digits are in each case represented by a single piece of cartilage, which differs very decidedly in appearance from the second digit (fig. 28) of embryo D. The outer surface of each was rough and pitted near its apex, but there was no external indication of phalangeal joints. Evidently in E the development of the second and fourth digits had been arrested at an earlier stage than in D. On making longitudinal sections, the metacarpo-phalangeal joint was seen to present very much the appearance represented in figure 34*a*, but there was no indication of even the distal phalangeal joint. The vestige of the phalanges of the second digit measures ·6 mm., that of the fourth ·5 mm. Compared with D, they are considerably larger, though not so well developed. It is worth noting further, that, compared with the third metacarpal, the second and fourth are relatively longer (figs. 31 and 32) than in D (fig. 30). Evidently the relation between the second and fourth metacarpals and the third is far from constant; but apparently this in most cases results more from the third metacarpal being relatively long than from the second and fourth metacarpals being relatively short when compared with the humerus. Embryo E (which fairly well indicates the stage reached at the middle of pregnancy, *i.e.*, at the sixth month) is especially interesting for the following reasons :—

(1) The skeleton of the fore-limb agrees with that of the adult not only in having the various segments of the same or nearly the same relative length, but also of nearly the same form; (2) the absence of osseous deposits in the carpals and in the epiphyses of the long bones; (3) the shaft of the ulna is more completely ossified than in Embryo D, and the expanded distal epiphysis is still free, and large enough to prevent the radius articulating with the cuneiform; (4) the trapezium (*c.* 1) is present, and articulates with both the trapezoid (*c.* 2) and the second metacarpal; (5) the third metacarpal is relatively longer than in "Hermit," and hence indicates that Embryo E has already assumed secondary characters; (6) the second and fourth metacarpals are relatively longer than in D, but the vestiges of their respective digits are less complete, either owing to earlier arrest in development, or to greater degeneration; and (7) the semilunar sinus is making its appearance in the terminal phalanx.

### (6) EMBRYO F (60 cm.).

Having described a six months embryo, I shall next consider a seven months embryo (F). As there is very little difference between a sixth and seventh month embryo except in size, a very short description of F will suffice. This embryo, which was 60 cm. in length, was out of a large (Shire) English mare. The humerus (Table I.) is nearly 2 cm. longer than in E, and the radius is of practically the same relative length as in "Hermit" —actual length is 10·70 cm., calculated length is 10·50 cm. The third metacarpal, however, is relatively longer than in "Hermit"—the difference between the actual and calculated lengths being 1·32 cm., and the united phalanges are also longer. Table III. shows that the metacarpo-humeral index in F is 90·42 (in "Hermit" it is 76·11, in E 88·15); Tables IV. and V. indicate that the relation of the united phalanges and the first phalanx to the humerus is similar to that of E, and Table VI. shows that the length from the hock to the tip of the hoof[1] is greater than in E, and nearly the same as in D. In F the humerus is relatively thicker than in E, the ulna is relatively larger, the shaft is ossified to within 4 mm. of its distal end, but the distal epiphysis, though still articulating with the whole of the proximal surface of the cuneiform, is partly united in front to the epiphysis of the radius. In all the long bones the ossification was relatively more extensive than in E; the centre in the second phalanx was relatively larger, and in the third phalanx the semilunar sinus was more distinct, and presented at least one large aperture in its outer wall. A yellow-coloured mass, consisting mainly of fat-cells, was seen in sections lying above the semilunar sinus. This evidently represented the marrow, and occupied a developing medullary cavity.

The second and fourth metacarpals, their respective vestigial digits included, were of the same length—6·5 cm., *i.e.* 2 cm. less than the third metacarpal. Figure 34 represents the fourth

[1] In all the embryos examined the hoof was long and pointed, and quite unlike that of the adult, as it doubtless is unlike the ancestral hoof—in the hoof there is no indication of recapitulation of ancestral characters.

metacarpal (IV.) and its vestigial digit (*p*), and figure 34*a* represents the lower end of the second metacarpal and its digit ten times natural size. Figure 34*a* proves conclusively that the elongated cartilage at the distal end of the splints is not, as has been suggested, an epiphysis. There is (1) the ossified distal end (*s*) of the shaft and the equally evident distal epiphysis (*e*) with large cartilage cells in rows in the vicinity of the new bone at the end of the shaft; (2) a fairly well formed diarthrodial joint, with a capsule (*c*) and an extensive cavity (*j*); and (4) the all but completely blended phalanges (1. 2. 3). The fourth metacarpal carried a similar vestige, and the metacarpo-phalangeal joint appeared to be even better developed—there was free movement in the antero-posterior direction, and when the capsule was opened a deep furrow was seen to separate the epiphysis from the rudimentary digit; when the digit was slightly pulled the furrow became a cleft, which indicated that there was little, if any, actual union between the metacarpal and its digit. Neither in embryo F nor in any larger embryo have I detected such a cap as was present at the end of the second digit in embryo D, but even in large embryos an imperfect joint sometimes persists between the second and third phalanx. In F, as in most embryos, the vestigial digits were slighty asymmetrical, and had their distal ends flattened from side to side. The apex of each was rounded.

The limb of embryo F presents generally the same characters as embryo E, but its various segments are, when compared with "Hermit," somewhat longer, as will be learned by referring to the Tables.

### (7) Embryo G (65 cm.).

I shall next refer very shortly to an embryo only about 5 cm. longer than embryo F. In this embryo the measurement from the hock to the tip of the digit was 28 cm., which is relatively more than in any of the smaller embryos. The humerus taken as 100, the length from the hock to the ground is in G = 261. In keeping with this length of the pes, the third metacarpal is relatively long (Table III.). On the other hand, the first phalanx is relatively slightly shorter than in F. Notwithstanding these variations of the manus and pes, the radius has still nearly the

same relation to the humerus as in "Hermit" (Table II.). All the segments of the limb in G were relatively more massive than in the smaller embryos, and, as in E, the second and fourth metacarpals were relatively long and the vestigial digits, though relatively thicker, very closely resembled those of embryo F—the tip of the fourth digit, however, curved more outwards and backwards than in F. Although the history of G was incomplete, there was every reason to believe that it belonged to a heavy breed of horses with relatively long hind-legs.

### (8) EMBRYO *Ga* (65 cm.).

In the embryos D, E, F and G, the various segments of the fore-limb have been, as Table I. indicates, of nearly the same relative length as the corresponding segments in "Hermit." I now come to deal with an embryo which in several respects greatly differs from "Hermit." This embryo, being of the same length as G (65 cm.), will be known as *Ga*. On first seeing this embryo it was evident that the legs were relatively longer than in any of the embryos previously examined. With the humerus taken as 100, the distance from the hock to the tip of the digit was = 296·29. That the humerus bears a relation to the length rather than the height of the horse is strongly suggested not only by adults but also by embryos. Evidence of this is especially found when G and *Ga* are compared. In G the length of the fore-limb, measuring from the olecranon process of the ulna to the tip of the hoof, was 36 cm., in *Ga* 42·5 cm.; the difference in the length from the hock downwards has already been mentioned. But notwithstanding that the forearm and manus of the one was over 6 cm. longer than the other the humeri were practically the same—in G 10·7, in *Ga* 10·8. But while in G the radius was of the same relative length as in "Hermit," in *Ga* (which belonged to a long-legged Irish breed) the radius was 2·22 cm. relatively longer than in "Hermit" (Table I.). Hence the radio-humeral index which in "Hermit" is 111·94 is in *Ga* 132·40. Even more striking is the length of the third metacarpal. It measures in *Ga* 12·20 cm.; to be of the same relative length as in "Hermit" it need only measure 8·22 cm. In other words, as Table III. shows, while the third metacarpal

in "Hermit" is 76·11, the humerus being 100, in *Ga* it reaches 112·96, or about relatively half as long again as in "Hermit." As Table IV. shows, the united phalanges are relatively very long, as is also the first phalanx (Table V.).

How is the great absolute difference between G and *Ga* and the great relative difference between *Ga* and "Hermit" to be accounted for. I think there can be no doubt that the differences are due to their belonging to different breeds. "Hermit" was only 15·2½ hands high, and was, as already mentioned, "short from the knee and hock to the ground." Some breeds are relatively long in the legs, and especially long from the knee and hock downwards to the ground. If the greater relative length of the radius and third metacarpal is due to *Ga* belonging to a long-legged breed of horses, we have further evidence that racial characters present themselves during embryonic life.

Even in embryo D the third metacarpal was relatively longer than in "Hermit." Perhaps D, had it continued to develop, would have in course of time presented the same characters as *Ga*. Evidently the great relative length of the third metacarpal in *Ga* was only partly due to the rapid growth of this bone in the embryo. Hitherto only in embryos belonging to long-legged breeds of horses has the metacarpal been relatively decidedly longer than in "Hermit." That the greater length of the third metacarpal is in most cases due to its growth being in the embryo more rapid than that of the radius is undeniable; but if, when further material is available, the third metacarpal is found to be invariably relatively very long in the embryos of some breeds and shorter in others, and if, in addition, the radius is only relatively long in embryos of very long-legged horses, there will be no escape, it seems to me, from the conclusion that the length of the third metacarpal in the embryo as in the adult partly depends on the breed, which, as already pointed out, implies that at a comparatively early period the fore-limb begins to assume special racial characters.

The second and fourth metacarpals and their vestigial digits were very similar in form to those of embryo F, but in their length they more intimately agreed with embryo D. For example, the fourth metacarpal was 3·7 cm. shorter than the third, while its degraded digit measured 7 mm.

The chief points of interest in embryo *Ga* are, that though of the same total length as G, and with the same length of humerus, it greatly exceeds G in the length of the radius (Table II.), the third metacarpal (Table III.), and the first phalanx (Table V.), and also in the greater length of the pes (Table VI.)—the differences between embryo G and "Hermit" being apparently mainly accounted for by *Ga* belonging to a longer-legged breed of horses.

### (9) EMBRYO H.

Having considered six and seven months embryos, I shall now deal with an eight months embryo (one of twins) from a strong-built 16-hands mare. Already I have indicated that the humerus very probably bears a relation to the length of the horse rather than to its height. I wish now to state that the third metacarpal seems to bear an intimate relation to the height rather than to the length. This seems to follow from a study of the tables, more especially from a comparison of the measurements of embryos G, *Ga*, and H. In embryo H, from a 16-hands mare, the third metacarpal measures 12 cm.; in a 17-hands mare, if of the same proportion, it would measure 12·18 cm. As Table I. shows, its actual measurement in *Ga* is 12·20 cm., *i.e.*, only 2 mm. more than the calculated length for a 17-hands breed. What holds for the third metacarpal also holds to a certain extent for the radius. In the 38-inch pony "Egil" the radial index (the humerus being 100) was practically the same as in the 15·2½-hands "Hermit." Probably it will be found that in horses from 9·2 to 15·2 hands the radius bears a constant, or nearly constant, relation to the humerus—varying only about ·40 cm. But probably in horses over 15·2-hands, the radius will be found relatively longer than in "Hermit,"[1] and as is the case with embryos *Ga* and H, the radius in embryos from horses over 15·2 hands in height will also be relatively longer.

Further information as to the lengths of the various segments of the fore-limb of embryo H will be found in Tables I.–VI. Though some of the bones are actually shorter than in the smaller embryo *Ga*, all of them are thicker and more like those

[1] In 16-hands horses measured, since this was written, the radius is nearly 5 cm. longer than in "Hermit."

of a Shire- than a race-horse. In a word, the various segments of embryo H suggest a heavier but smaller breed of horses than those of embryo G*a*.

The second and fourth digits in H were especially interesting in as far as they gave evidence of more marked degeneration than any of the smaller embryos. The second and fourth metacarpals were as in G*a* relatively short—the second measured 8·6 cm., the fourth 8·45 cm., while the third metacarpal measured 12 cm. The vestiges of the second and fourth digits measured 8 mm. and 7 mm. respectively. The metacarpo-phalangeal joints (fig. 35) seemed to the naked eye to be as well developed as in G and G*a*: there was, *e.g.*, a capsule and a shallow groove at the end of the epiphysis, but on examining sections the epiphysis and the vestigial digit were perfectly continuous—whether there had ever been an incomplete joint as in embryo F it is impossible to say. It may, however, be mentioned that the metacarpo-phalangeal joint of the second and fourth digits is not always absent in eight month embryos, and that there was no difficulty in distinguishing the second and fourth digits from their respective metacarpals in a one month foal.

Embryo H may be said to be of interest through its confirming the view that the relatively greater height of embryos from mares over 15·2 hands is mainly attained by an increase in the length of the third metacarpal, and, though in a less degree, by an increase in the length of the radius. It is further interesting in having the vestiges of the second and fourth digits of at least the left fore-limb continuous with their respective metacarpals. The measurements of an embryo (H*a*) about 4 cm. longer than H have been introduced into the tables to admit of a comparison being made between two embryos of nearly the same size but of different breeds—H*a* being from a well-bred mare.

## (10) EMBRYO I.

I shall bring this second contribution to a close by describing the limb-skeleton of a nine months embryo. This embryo (I), which was from a large Shire-mare, measured 88 cm. in length. The relation to the humerus of the pes and of the fore-limb from the olecranon process downwards (Table VI.) indicates that it

probably belonged to a breed somewhat larger than embryo G, but smaller than embryos G*a*, H, and H*a*. The relative difference in the diameters of the humerus radius and third metacarpal pointed to G*a* belonging to a finer breed than embryo I, as indeed was the case.

The humerus (fig. 37), though only 15·75 cm. in length, closely resembles that of the adult, and has a greater diameter at the centre of its shaft than that of "Egil," in which the humerus is over 6 cm. longer. The muscular processes are, however, smaller than in "Egil," though considerably larger than in H and the other embryos. The grooves on the summit of the great tuberosity are relatively deep, the outer condyle is bent outwards, and the inner projects well over the olecranon fossa. When the height of the embryo is considered, the humerus is relatively short, but when the length of embryo I is considered, the humerus is relatively longer than in "Eclipse."

The radius (1·17 cm.—relatively longer than in "Hermit") is nearly as well developed as the humerus. Though nearly 7 cm. shorter than that of "Egil," its circumference is slightly greater. Its relation to the upper end of the ulna is similar to that of the adult, and its lower end presents articular surfaces for the scaphoid (radiale) and semilunar. While its epiphysis encroaches on the lower end of the ulna, it has no connection with the cuneiform (ulnare). As fig. 37 shows, the shaft is well ossified, and more curved than is usually the case in the adult.

The ulna now lies more under cover of the radius than in smaller embryos, and its olecranon process closely resembles that of the adult. The shaft, though closely applied to the radius, has not yet united with it. With the exception of a small portion opposite the last 4 mm. of the shaft of the radius, the shaft of the ulna is well ossified. Beyond the slender unossified part of the shaft comes the distal epiphysis, which forms a wedge-shaped mass that fits in between the radius and the cuneiform, with the whole of which it articulates. Even in this large nine months embryo the union of the distal epiphysis of the ulna with the expanded end of the radius has not yet been completed in front, and there is a distinct gap between them posteriorly. The carpal region is still slightly longer relatively than in the adult. There is no trapezium, and no

indication externally of ossification of the carpals. The third metacarpal, though relatively shorter than in *Ga*, is actually wider and longer than in the 38″ pony (Table I.), and 5·27 cm. relatively longer than in "Hermit."[1]

The united phalanges are nearly as long as in "Egil" (Table I.), and the first phalanx (5·25 cm.) is relatively longer than in "Hermit" (Table V.), and the second phalanx (2·50 cm.) is well ossified, although true bone has not yet reached the front surface. The third phalanx (3·8 cm.) is relatively very small, and in form quite unlike that of the adult. Fig. 37[a], which represents a section, natural size, shows a cavity in the position of the most distal part of the phalanx proper. The greater part of this cavity was occupied by soft fatty tissue. It seems to represent a medullary cavity as well as the semilunar sinus. In the section the upper or front wall—so thick in the adult—is seen to be still quite thin—relatively thinner than in embryo D. The cap has encroached well on to the phalanx, which is now well ossified. There is not yet any indication of a true bony epiphysis.

The second and fourth metacarpals are, compared with the third, relatively short; the second, including the distal epiphysis, measures 12·2 cm.; the third 12·3 cm. In each case the unossified proximal end measures 1·2 cm.; the vestigial second digit measures 1·0 cm.; the fourth 1·1 cm. The "splints," which are closely applied to the third metacarpal, gradually taper from above downwards, and each ends in an epiphysis little over 1 mm. in length. The degenerated fourth digit is represented in figure 36. Beyond the metacarpo-phalangeal joint, which closely resembled that in embryo F, the digit expanded, and then ended in a blunt point. The phalangeal joints had entirely disappeared. The second digit, slightly smaller than the fourth, was more regular in form, the tip being rounded and less prominent.

In almost every respect the fore-limb of embryo I agreed,

[1] As an indication of the rate at which the metacarpal grows during the latter months of embryonic life, I may mention that at birth a foal belonging to the Shire-breed may have its third metacarpal measuring 24 cm., *i.e.*, only 1·5 cm. shorter than in "Hermit." It is by many supposed that there is no increase in the length of the third metacarpal (cannon bone) after birth. I shall show later that this is not very wide of the truth. The limbs are infinitely more specialised in the adult horse than in Man. Yet, though it may seem paradoxical, they are more specialised in the foal than in the adult horse.

except in size, with that of embryo G, and differed from the better bred and longer legged embryos G*a* and H*a*. The humerus, when the length rather than the height was considered, was longer than in "Eclipse," while the radius (5·52 cm.) and the third metacarpal (33·41 cm.) were relatively longer than the respective bones in "Hermit," though relatively shorter than in embryo G*a* (Tables II. and III.). In the relative length of the united phalanges and of the first phalanx, embryo I agreed with embryos H and H*a*, but differed considerably from G in the one direction and embryo G*a* in the other. Compared with the other parts of the limb, the os pedis was small, and in having a wedge-shape on section, it differed greatly from the os pedis in the adult.[1]

[1] To A. J. Haslam, Esq., M.B., F.R.C.V.S., of the Army Veterinary Department, I am indebted for embryos E, G and G*a*.

Embryos F, G and I were received through Professor Mettam, and embryo H from S. Beeson, Esq., M.R.C.V.S., Hereford.

I have also much pleasure in expressing my gratitude to Professor M'Fadyean, of the Royal Veterinary College, London; Professor Stewart, of the Royal College of Surgeons' Museum, London, for providing facilities in connection with my investigations; and to A. Hodder, Esq., Roy. Dick College, Edinburgh, for several excellent drawings.

## DESCRIPTION OF PLATE XII.

Fig. 26. Two last phalanges (2 and 3) of third digit of a full grown Proteus: *c*, bony cap investing last phalanx; *d*, articular disc.

Fig. 27. Rudiment of second digit from embryo B (25 mm.).

Fig. 28. Second digit of embryo D (35 cm.).

Fig. 28$^a$. Cap from tip of second digit shown in fig. 28.

Fig. 29. Fourth digit of embryo D, 10 (not as stated 8) times nat. size.

Fig. 30. Second and fourth metacarpals of embryo D, and their "unwrapped" digits as seen from behind, nat. size.

Fig. 31. Left fore-limb, embryo E, nat. size.

Fig. 32. Front view of same limb $\frac{3}{8}$ (not $\frac{1}{4}$ as given in plate) nat. size.

Fig. 32$^a$. Terminal phalanx of same limb from behind, showing notches in cap (3$^a$) for plantar arteries.

Fig. 33. Second and fourth metacarpals and digits of embryo E, as seen from within and without respectively, nat. size.

Fig. 34. Fourth metacarpal and digit of embryo F, nat. size.

Fig. 34$^a$. Section showing lower end of shaft (*s*) of second metacarpal, and its epiphysis (*e*); the vestigial second digit (1, 2, 3.); the metacarpo-phalangeal joint (*j*) and its capsule (*c*). Embryo F 10 times nat. size.

Fig. 35. Fourth digit (1) and the lower end of the fourth metacarpal of embryo H, 3 times nat. size.

Fig. 36. Second digit of embryo I, 3 times nat. size.

Fig. 37. Left fore-limb of embryo I, $\frac{7}{8}$ nat. size.

Fig. 37$^a$. Section through os pedis of same, nat. size.

*c*, cuneiform (ulnare), in fig. 26, bony cap; *d*, disc between phalanges; *e*, epiphysis; *h*, humerus; *j*, joint; *l*, semilunar; *m*, magnum (*c*. 3); *p*, pisiform, in figs. 30, 33, and 34 phalanges; *r*, radius; *r'*, trapezoid (*c*. 2); *s*, shaft; *s'*-*s''*, unossified part of ulna (fig. 31); *u*, ulna; *u'*, unciform (*c*. 4 and 5); 1, 2, 3, first, second, and third phalanges; 3' and 3$^a$, cap of terminal phalanx.

## TABLE I.

Table showing the actual length of the Humerus, the Radius, the Third Metacarpal, and the Three Phalanges; and also the length the Radius, &c., would have if of the same relative length as in "Hermit."

| | Humerus. | Radius. | | Metacarpal III. | | Three Phalanges. | |
|---|---|---|---|---|---|---|---|
| | | Actual length. | Calculated length. | Actual length. | Calculated length. | Actual length. | Calculated length. |
| | cm. | cm. | cm. | cm. | cm. | cm. | cm. |
| "Hermit" (15·2½ hds.) | 33·50 | 37·50 | ... | 25·50 | ... | 19·50 | ... |
| "Eclipse" (15·3 hds.) | 33·00 | 37·60 | 37·26 | 25·80 | 25·11 | 19·00 | 19·20 |
| "Egil" (38 inches) . | 22·4 | 25·00 | 24·70 | 17·00 | 17·00 | 12·80 | 13·03 |
| Ass . . . . . . | 21·70 | 25·00 | 24·29 | 17·75 | 16·51 | 11·80 | 12·63 |
| Zebra . . . . . . | 25·30 | 28·40 | 28·30 | 18·80 | 19·25 | 13·20 | 14·72 |
| Hipparion . . . . | 24·00 | 25·50 | 26·80 | 21·30 | 18·26 | 10·70 | 13·97 |
| *Mesohippus* . . . . | 12·50 | 12·25 | 13·90 | 9·37 | 9·51 | 3·34 | 7·28 |
| *Hyracotherium* . . . | 9·60 | 9·30 | 11·04 | 4·80 | 7·30 | 2·17 | 5·58 |
| *Phenacodus* . . . . | 17·30 | 14·50 | 19·36 | 7·20 | 13·16 | 6·00 | 10·07 |
| Embryo A (20 mm.) . | ·30 | ·20 | ·33 | ·13 | ·26 | ·12 | ·17 |
| " B (25 mm.) . | ·34 | ·27 | ·37 | ·19 | ·25 | ·19 | ·19 |
| " C (50 mm.) . | ·70 | ·65 | ·78 | ·42 | ·50 | ·43 | ·40 |
| " D (35 cm.) . | 5·50 | 6·15 | 6·15 | 4·60 | 4·15 | 3·15 | 3·20 |
| " E (50 cm.) . | 7·60 | 8·50 | 8·50 | 6·70 | 5·78 | 5·00 | 4·39 |
| " F (60 cm.) . | 9·40 | 10·70 | 10·50 | 8·50 | 7·18 | 6·50 | 5·47 |
| " G (65 cm.) . | 10·70 | 12·00 | 11·97 | 10·00 | 8·14 | 6·70 | 6·22 |
| " *Ga* (65 cm.) . | 10·80 | 14·30 | 12·08 | 12·20 | 8·22 | 8·10 | 6·28 |
| " H (73 cm.) . | 11·30 | 13·50 | 12·64 | 12·00 | 8·60 | 7·80 | 6·57 |
| " *Ha* (77 cm.) . | 13·00 | 16·00 | 14·55 | 14·70 | 9·89 | 8·80 | 7·56 |
| " I (90 cm.) . | 15·75 | 18·50 | 17·33 | 17·25 | 11·98 | 11·00 | 9·16 |

## TABLE II.

RELATION OF THE RADIUS TO THE HUMERUS.

(*Humerus* = 100.)

| | | | |
|---|---|---|---|
| Phenacodus, . . | 83·81 | Embryo A, . . | 66·66 |
| Hyracotherium, . | 93·79 | " B, . . | 83·52 |
| Mesohippus, . . | 98·00 | " C, . . | 92·85 |
| Hipparion, . . | 106·25 | " D, . . | 111·81 |
| Zebra, . . . | 112·25 | " E, . . | 111·84 |
| Ass, . . . | 115·20 | " F, . . | 113·82 |
| "Egil," . . . | 111·61 | " G, . . | 112·14 |
| "Hermit," . . | 111·94 | " *Ga*, . . | 132·40 |
| "Eclipse," . . | 113·93 | " H, . . | 119·47 |
| | | " *Ha*, . . | 123·07 |
| | | " I, . . | 117·46 |

## TABLE III.

RELATION OF THIRD METACARPAL TO THE HUMERUS.

(*Humerus* = 100.)

| | | | |
|---|---|---|---|
| Phenacodus, | 41·61 | Embryo A, | 45·00 |
| Hyracotherium, | 50·00 | „ B, | 55·88 |
| Mesohippus, | 74·49 | „ C, | 60·71 |
| Hipparion, | 88·75 | „ D, | 83·63 |
| Zebra, | 74·30 | „ E, | 88·15 |
| Ass, | 81·79 | „ F, | 90·42 |
| "Egil," | 75·88 | „ G, | 93·45 |
| "Hermit," | 76·11 | „ Ga, | 112·96 |
| "Eclipse," | 78·17 | „ H, | 106·19 |
| | | „ Ha, | 113·07 |
| | | „ I, | 109·52 |

## TABLE IV.

RELATION OF THE THREE PHALANGES TO THE HUMERUS.

(*Humerus* = 100.)

| | | | |
|---|---|---|---|
| Phenacodus, | 34·68 | Embryo A, | 40·00 |
| Hyracotherium, | 22·60 | „ B, | 55·88 |
| Mesohippus, | 26·72 | „ C, | 55·71 |
| Hipparion, | 47·91 | „ D, | 57·27 |
| Zebra, | 52·17 | „ E, | 65·78 |
| Ass, | 52·99 | „ F, | 67·55 |
| "Egil," | 57·14 | „ G, | 62·61 |
| "Hermit," | 58·20 | „ Ga, | 75·00 |
| "Eclipse," | 57·57 | „ H, | 69·02 |
| | | „ Ha, | 67·69 |
| | | „ I, | 68·57 |

## TABLE V.

RELATION OF FIRST PHALANX TO HUMERUS.

(*Humerus* = 100.)

| | | | |
|---|---|---|---|
| Phenacodus, | 19·20 | Embryo A, | 20·00 |
| Hyracotherium, | 12·50 | „ B, | 21·80 |
| Mesohippus, | 14·28 | „ C, | 22·28 |
| Hipparion, | 20·37 | „ D, | 26·36 |
| Zebra, | 26·87 | „ E, | 26·31 |
| Ass, | 29·63 | „ F, | 29·25 |
| "Egil," | 25·44 | „ G, | 28·03 |
| "Hermit," | 25·37 | „ Ga, | 35·18 |
| "Eclipse," | 26·66 | „ H, | 29·20 |
| | | „ Ha, | 32·69 |
| | | „ I, | 31·11 |

## TABLE VI.

RELATION OF PES (HOCK TO TIP OF HOOF) AND OF FORE-ARM AND MANUS TO HUMERUS.

(*Humerus* = 100.)

| | *Pes.* | *Fore-arm and Manus.* |
|---|---|---|
| Embryo C, | 121·42 | ... |
| " D, | 236·36 | ... |
| " E, | 231·57 | 315·78 |
| " F, | 239·36 | 331·90 |
| " G, | 261·68 | 336·44 |
| " G*a*, | 296·29 | 393·51 |
| " H, | 276·10 | 371·68 |
| " H*a*, | 276·92 | 357·69 |
| " I, | 274·28 | 339·68 |

(*To be continued.*)

## REPORT ON RECENT TERATOLOGICAL LITERATURE. By BERTRAM C. A. WINDLE, D.Sc., M.D., M.A., *Professor of Anatomy in Mason College, Birmingham.*

IN this fourth report on Teratological Literature, the writer has proceeded on similar lines to those of former years. He has again to express his indebtedness to those authors who have been good enough to send him copies of their papers, and to request them and others to be so kind as to supply him with any further communications dealing with the subject, for use in the preparation of future reports.

GENERAL.—Giacomini (I.) describes a still further stage to that of the nodular embryos with which he has dealt in former communications; a stage, that is, where, of all the structures connected with the embryo, only the chorion persists with almost normal characteristics. Of this condition two instances are described. In both, the chorionic cavity was full of the magma reticularis (described by the author recently, "Sul Cœloma Esterno e sul Magma Reticularis nell' Embrione Umano," *R. Acc. di Med. di. Torino*, vol. xli.). The development of the embryo with all its dependencies has been initiated, but it has died and undergone a process of destruction, by which all its constituent elements have become dissociated and absorbed, so that nothing is left of it which can be recognised. In his twelfth observation, which concludes the paper now under consideration, there is an account given of a case in which the embryo is in process of destruction, but still in part recognisable. Lachi (II.) describes an anomalous human ovum, which consisted of a small transparent vesicle, containing a minute nodular embryo, with an umbilical vesicle. The remains of the embryo were infiltrated with small round cells, and contained in their centre a tube partly lined by epithelium, which was probably the umbilical duct.

Mulden (III.) gives an account of an acephalus paracephalus, which commences with a general discussion of the subject, illustrated by cases. His own specimen possessed a rudimentary skull, with obvious superior and inferior maxillæ. There was no brain, but the author states that the facial nerve could be distinctly made out in its distribution over the face. The liver and spleen were present, and provided with large arteries; but the sympathetic system and the supra-renals were totally absent.

Odisio (IV.) gives a description of the anatomy of a sirenomelic fœtus, with the microscopic examination of its spinal cord. The latter was normal down to the lower end of the lumbar region, in which region there appeared between the central canal and the anterior fissure a band, sufficiently well defined by its limits and by the character of the elements of which it consisted. Its limits were formed by horizontal fibres, which started from near the central canal, and passing forwards, diverged to inclose between them a strong band of

longitudinal fibres. The termination of these fibres appeared to be in the ground substance of the anterior columns, but it was not easy to say which of the bundles, abnormally disposed, they represented. At the most, it might be supposed that there was a heterotopia of the nervous substance, due to the same cause which produced the malformation of the fœtus, possibly a torsion of the posterior extremity of the embryonic axis. Such a theory might be supported by the appearance of the central canal in the same part. This presented the appearance in other parts of the cord of a linear cleft, slightly enlarged at its anterior end. At the part above mentioned it became curved upon itself, so as to look like a V with the apex directed forward. In other places the appearance was that of two central canals, each lined with its own layer of epithelium.

V. Leonowa (V.) deals in his paper with the examination of the nervous system of an anencephalous fœtus, in which there was total rachischism, accompanied by complete absence of the spinal cord. The posterior ganglia and peripheral nerves arising from them were present, as also the sympathetic system, from which he concludes (1) that the development of the peripheral sensory nerves does not depend upon the central nervous system, seeing that they may originate and develop progressively, in the total absence of the brain and spinal chord; (2) that the peripheral sensory nerve fibres arise from the cells of the intervertebral ganglia, and are the prolongations of their axis-cylinders, so that we ought to look upon the cells of the intervertebral ganglia as a primary nucleus, the true nucleus of a sensory fibre.

Sulzer (VI.) gives a careful account of the literature of cases of spinal bifida, accompanied, as in his case, by duplicity of a part of the spinal cord. In the instance which he describes, the spina bifida was in the lumbar region, and at the level of the third lumbar vertebra a peg-like ecchondrosis sprang from the body of the vertebra which separated the cord into two parts, which reunited at the cauda equina. The microscopic examination is given in great detail. Besides doubling of the cord, there was a dilatation of the central canal, which extended to the medulla. There was also present an extensive process of degeneration, especially in the lateral tracts of the dorsal and cervical regions. (In connection with this point, attention may be drawn to the first of these reports, in vol. xxv. of this *Journal*, in which a similar case described by Steffen is given, together with the opinions of Humphry and Cleland on the subject.)

Kollmann (VII.) deals with the relation between spina bifida and the neurenteric canal, in connection (1) with the observation that eggs incubated at a temperature higher than the normal show a persistent neurenteric canal in connection with a spina bifida; and (2) with a fœtus which he has examined, which was affected with spina bifida. "As a result," he says, "of the separation of the embryonic anlage into two halves, or, to speak embryologically, as a result of the arrested union of the two lips of the blastopore, the spinal cord and the notochord become doubled. The unpaired medullary groove, and the medullary plate arising from it, as well as the notochord, thus

exist as two halves. The development of these halves provides each half of the body with its own medullary canal and notochord. The reunion of the separated canals and notochords on each side of the cleft do not close it. This is an interesting example of the energy of the developing embryo in overcoming obstacles, and also an important proof that division of such important organs even of the medullary canal and notochord does not always lead to a double embryonic anlage, but to the cleavage of a normally single organ." The author thinks that in Man an abnormal increase in size of the neurenteric canal may lead to the production of a spina bifida. The production of this peculiar kind of spina bifida he describes as follows:—(1) The separation takes place first of all in the earliest part of embryonic life, through cleavage of the medullary plate from the neurenteric canal onwards. A similar cleavage of the spinal cord can, so far as present experimental embryology shows, be artificially produced by over-matured, over-fertilised, or overheated ova. (2) The two separated halves of the medullary plate develop into two separated and hydropically dilated spinal cords (myelocele). Such a formation of two or even more tubes may be artificially produced. (3) Formation of a meningocele in the form of a lumbo-dorsal dural sac, which is only proximally connected with the spinal dura mater; (4) ventrad to this dural sac exists, on account of the marked lordosis, a considerable subdural space, through which the lumbo-dorsal nerve trunks pass to the intervertebral foramina.

Emery (VIII.), dealing with the subject of cyclopia, thinks that, though it is not proved, it is highly probable that (1) the tube-like malformed nose corresponds to the pouch of the hypophysis; (2) that this pouch is placed preocularly; (3) that the way to the infundibulum is closed by the union or close approximation of the primitive ocular vesicles. He states that whilst he does not look upon cyclopia as being atavistic in its nature, he thinks that the process of ventral approximation or union of the optic vesicles has a great similarity with a conceivable reversion, as, in cyclopia, the eye rudiments wander from the inverted position which they take up in normal development, since they, in the former condition, approximate to one another caudal to the hypophysis, *i.e.* on its ventral aspect, whilst in the latter they tend dorsad and forwards. There exists, therefore, in cyclopia a condition which appears to him to agree in many respects with that of the invertebrate primitive stem of vertebrates.

Duplicity.—Hoffmann (IX.) describes and figures a very young double embryo of a chick (anadidymus), his microscopic examination of which shows duplicity of part of the embryo, which presents in its posterior portion a single primitive groove, which at its anterior end divides into two portions, each of which forms an embryo. The specimen is thus an anadidymus, in which the cleavage is carried a considerable distance backwards towards the caudal extremity, where it is single. The two embryos do not diverge from one another for any great extent, and each is provided with a perfectly distinct notochord. But as the space between them is limited, the regular development of the adjacent sides was impossible: hence there is a common head, a

common wide foregut, and a common widely-open medullary groove. Besides these easily explicable appearances, there are also two laterally divergent projections from the primitive streak which might be looked upon as two further rudimentary embryos, in which case the monster would be quadruple. The author does not consider this explanation satisfactory, but thinks that these last described appearances must be grouped with the not unfrequently observed crescentic forms (sichelartigen bildungen) of the embryonic discs of reptiles and birds.

Various authors (X.) have described a pair of xiphopagous sisters, Radica-Doodica Khettronaïk, who were born in September 1889, in the province of Orissa, of a mother who had previously had five well-formed children. Radica measures 84 cm., Doodica 87. Their weight is 24 kgs. The cephalic index of Radica is 72, and the horizontal circumference of her head is 480 mm. The corresponding figures for Doodica are 75 and 474. The point of union extends from the umbilicus to the centre of the xiphoid cartilage, and measures 10·5 cm. in height, 8 cm. in length, and 28 cm. in circumference. It is sufficiently lax to permit of the sisters sitting on a chair like two ununited individuals. They walk a little sideways, with their posterior arms over one another's shoulders. One can sleep on the back whilst the other is on her side. The coxo-femoral articulations are so lax that the children can sit on their ischiatic tuberosities with their lower limbs crossed. The pedicle of union presents at its superior part, under the skin, an osteo-cartilaginous bridge, 2–3 cm. long, larger than a thumb, cylindrical, and constituted by the inferior parts of the united xiphoid cartilages. From each side of this there is a short osteo-cartilaginous prolongation. Authorities seem to differ as to whether one of them has inversio viscerum.

Taruffi (XI.) describes the case of a child with a round tumour, the size of a child's head, depending from the middle of the abdominal wall, between the umbilicus and pubes. At first intra-abdominal but extra-peritoneal, it escaped at the age of eight from an aperture which had been present from birth. The tumour was lobulated, and bore hair in parts. It was removed, and on examination was found to possess in one part of its interior a superior maxilla, apparently of the right side, with a premaxilla provided with two alveoli, one of which contained a tooth. The question is considered as to whether the tumour is to be considered as a true parasite or as derived from the ovary, and a list of illustrative cases concludes the paper.

The *Catalogue of Monstrosities* in the Museum of the University of Helsingfors, recently published, and kindly sent to me by the authors, during the past year (XII.) contains a good account of an interesting case of a human parasite—Dipygus parasiticus — male. From the right side of the thorax spring the arms of the parasite, and close under them the legs. One of the arms is well developed; in the other, the forearm is very short, and the hand, which is only provided with four fingers, is placed at right angles to it. The lower extremities, which have between them a membranous penis, cannot be extended at the knee on account of the tightness of the skin. Each

foot has only three toes. There was also an umbilical hernia present in the autosite.

HEAD AND NECK.—Broca (XIII.) adds another to the list of congenital tumours of the mouth. In the case in question, the tumour sprang from the back of the symphysis menti, and reached to the top of the pharynx. It caused bifidity of the tongue. (This is apparently a teratoma of the basi-sphenoid. Accounts of similar cases collected by Arnold will be found in Virchow's *Archiv*, t. cxi. s. 176 (38 cases). See also papers by Abraham and the present writer, this *Journal*, vols. xv. p. 244, and xxii. p. 423). Genouville (XIV.) gives a case of congenital cyst of the middle line of the neck. The tumour, which was the size of an orange, hung from the lower part of the mid cervical region. It appeared for the first time (of the size of a nut) at the first menstruation, and increased considerably after marriage. It was removed, and proved to be a congenital cyst, containing a yellow, homogeneous, slightly greasy substance. It was lined internally with epithelium, and no glandular elements could be discovered in its substance. The author notes that M. le Dentu has recently pointed out that median cysts of the neck are rare (he only knows of six, several of which had retro-sternal prolongations); also that whilst the lateral cysts of this region contain hairs, the median have not yet been shown to possess them. Faure (XV.) adds another to the list of median cervical cysts, having discovered one in a dissection subject. It occurred in the space between the hyoid bone and the thyroid cartilage, and was attached to the posterior surface of the former and to the front of the thyro-hyoid membrane. Its contents were apparently mucous, but its condition did not permit of any accurate microscopic examination. It appeared to have developed at the expense of the embryonic diverticula, normally producing the thyroid body. Tellier (XVI.) gives a case of geminated incisor. A child of ten years old presented two central upper permanent incisors of unusual breadth. The right especially was more than a centimetre in width, and showed at the union of the inner with the two outer thirds a groove on the labial surface which continued to the neck on the lingual aspect. With the aid of the electric lamp, it was established that it possessed only one root and one pulp-cavity. Weil (XVII.) has a similar but much rarer case—so rare indeed that he has been unable to discover another—in which the right upper median incisor had two fangs, and was obviously formed by the fusion of the normal with a supernumerary tooth. This tooth was removed for caries; that of the left side, which was healthy, was in other respects like that described. The same paper narrates an instance of a supernumerary left upper wisdom-tooth.

V. Leonowa (XVIII.) has an important paper bearing on the secondary changes in the brain consequent upon anophthalmia and atrophy of the optic bulb. Microscopically, there can be seen in the cortex of the sulci calcarini various layers, which are from without inwards as follows:—(1) Ependymal layer, with scattered neuroblasts. (2) Layer of close-lying neuroblasts. (3) Layer of less closely-lying neuroblasts. (4) Layer of clear striæ, with scattered neuroblasts.

(5) Layer of close-lying small elements (? granular layer), sometimes mixed with large neuroblasts. (6) Outer striæ of Baillarger. (7) Baillarger's intermediate layer. (8) Inner striæ of Baillarger. The changes in these layers are as follow :—(1) In anophthalmia and in atrophy of the bulb several of the layers fail completely. (2) Those which remain are more or less subjected to atrophy. (3) The completely failing layer is the fourth. (4) The fifth layer is least subject to atrophy; the larger cells have disappeared, the smaller are only atrophic, not appearing to be diminished in number. (5) In anophthalmia all the nuclei are remarkably smaller than in the control preparation. In atrophy of the bulb they are comparatively larger. The fourth layer, from its complete disappearance, would appear to be of great importance in connection with the sense of sight. Leaving aside the question as to which part of the retina the absent cells and layers in the cortex are connected with, the author considers that it is established that the occipital lobe in general, and especially the cuneus and edge of the calcarine sulcus, with its fourth layer as the most important part, form a true centre of vision.

Itzig (XIX.) describes a case of partial hypertrophy of the left side of the face and of the upper extremity of the same side. The patient was a boy of sixteen years of age, and the parents and other children were all normal and healthy. The left side of the face, and particularly that part of it below the zygoma, was larger than the right. The cleft for the left eye was the smaller of the two. The bones and muscles did not seem to share in the hypertrophy, and there was no difference between the two sides of the cavity of the mouth. The left ear was larger, thicker, and more prominent. The left upper extremity was thicker in all its parts than the right, and was of a brownish blue colour. There was no visible trace of arterial or venous enlargements, and the muscular power was equal on both sides.

TRUNK.—Launay (XX.) mentions a case in which the first lumbar vertebra bore a thirteenth pair of movable ribs. In the same subject the sacrum consisted of six pieces, the first of which was separated from the second by a very thin intervertebral disk. Soffianti (XXI.) gives an instance of heredity in mutiple abnormalities of the axis. A pregnant woman, her six months fœtus, and a former child aged three, all presented the same anomaly, viz., the existence of a thirteenth dorsal vertebra and thirteen pairs of ribs. Mortillet's note (XXII.) on the Manx cat may be mentioned in connection with these numerical abnormalities. As is well known, the tail in this breed is reduced to a hairy tuft, 2–3 cm. in length. This peculiarity is hereditary, and the author mentions an instance of crossing with a normal cat, which produced kittens with very rudimentary tails. This curious race is also met with in Japan, as Japanese pictures show, and in Malaysia, with a very short tail, sometimes twisted several times upon itself. It is possible that the Manx cats, instead of being an autochthonous race, as is generally believed, have been imported from the extreme East by sailors.

Ziclinski (XXIII.) gives a case of absence of both pectorals on one

side. The condition was recognised during life, and verified by a post-mortem examination. Zimmermann (XXIV.) gives an account of a much rarer form of the same abnormality. According to the author, only two similar ones are on record, whilst his is the thirty-fifth described instance of defect of the muscles without membranous formation. Many of these cases are complicated by syndactyly, absence of ribs, defective or exaggerated development of hair or adipose tissue, absence or incomplete development of the breast and nipple. The individual examined by the author came of a healthy family, and his parents and brother were in all respects normal. The right half of the thorax is much flattened, by palpation the complete absence of the muscles can be made out, and this the more easily as there is no breast nor adipose tissue. The nipple is greatly atrophied, little pigmented, and somewhat depressed in position, as is the right shoulder. The hair, which is normally developed on the left, is absent on the right. The serratus magnus is atrophied and thin. The place of the muscle is taken by a strong aponeurotic membrane, which does not prevent the arm being raised. The entire right upper extremity is smaller in its musculature, with the exception of that part belonging to the shoulder girdle, than the left. Electrical and other observations prove the case to be one of congenital absence of the muscles, and not one of atrophy from disease. The causes which have been assigned for the condition are compression of the part by an arm or by a uterine tumour, deficiency of liquor amnii, diseases of the fœtal annexes, traumatism, or atrophy of part of the spinal cord. It is interesting to note that movement of the arm upwards and downwards, as well as adduction, can be rapidly and swiftly effected by the vicarious action of the deltoid, latissimus dorsi, and subclavius, as Duchenne had previously pointed out.

Kollmann (XXV.) gives an account of a number of abnormalities in connection with the inferior vena cava, but it is impossible here to do more than call attention to the paper.

Proussolle (XXVI.) gives an account of a case of intestinal atresia occurring in a child which lived ten days. At the autopsy the portion of the intestine which was occluded was found to be 25 cm. above the iliocæcal valve. The superior and inferior ends of the intestine at the point of occlusion were separated by a distance of 5 mm. The cæcum was situated at the left side of the abdomen. The occlusion appears to have been situated exactly at the point of insertion of the umbilical duct, at the apex of the loop which is engaged in the cord.

V. Bardeleben (XXVII.) adds a fourth to the series of papers which he has contributed on the subject of hyperthelia. The observations in the present communication extend to over 107,000 men. The extent of the existence of supernumerary nipples in different districts of Germany is shown by tables and a map.

Extremities.—Blanc (XXVIII.) has dealt with the subject of polydactyly in an interesting paper, of which the following is a summary. After having defined the word and considered the various classifications which have already been proposed, the author suggests the

following as best corresponding to the different anatomical conditions and their teratological explanations. (1) Atavistic polydactyly, by reappearance of ancestral digits. (2) Teratological polydactyly, by division of normal or atavistic digits. (3) Heterogenic polydactyly, by formation of digits which result neither from atavism nor from schistodactyly (longitudinal division of the digit). Finally, there is a special variety of augmentation of the digits resulting from duplication of the extremity, or schistomelia, which must be distinguished from true polydactyly.

*Atavistic Polydactyly.*—It is first necessary to determine the number of digits possessed by the ancient forms from which the present races of animals are developed. In this the author accepts the opinion of Wiedersheim, who considers that the primitive manus and pes of mammals was heptadactylous. When, in a given individual, the number of digital rays is superior to that of the species to which it belongs, the rays are not absolutely new formations, but have resulted from the increase in size of normal structures which, under ordinary circumstances, remain rudimentary or disappear entirely. This growth is determined by local causes. The author does not consider that atavism intervenes to cause the reappearance of an organ which has entirely disappeared. Its function is reduced to the formation of rudiments which may disappear or develop according to circumstances. From the examination of different forms of atavistic polydactyly amongst mono-, di-, tetra- and pentadactylous mammals, he deduces some general principles:—(1) The more simple the extremity of a given species, the more varied and the more divergent from the normal type are the forms of polydactyly which may be met with. (2) In all species the thoracic member presents ancestral digits much more frequently than the pelvic, which leads to the conclusion that the hand has simplified later than the foot. (3) In Man the post-minimus appears more frequently than the pre-hallux or pre-pollex, other animals following the inverse law.

*Teratological Polydactyly.*—The author gives several examples of polydactyly caused by partial or complete longitudinal division of a digit. The cause of these malformations is very obscure. Albrecht, basing his opinion upon the duplicity of the pterygian rays of selachians, considers that the digits of other animals result from the fusion of two rays, in which case the division of digits would be a simple return to the ancestral condition. This theory, though quite hypothetical, seems to fit in with the facts, and the author seems to be disposed to accept it, at least provisionally.

*Heterogenic Polydactyly.*—In this category are placed certain forms which can neither be explained by atavism nor by schistodactyly—intercalary digits for example. It is necessary to wait for new facts before these forms can be definitely classified.

Finally, if Albrecht's view is accepted, teratological or schistodactylous polydactyly is also atavistic, and one only of the above-mentioned categories is really unrelated to actual or ancestral forms, namely, heterogenic polydactyly. In this case the classification would be as follows:—1st group, atavistic polydactyly.

(*a*) Reversion to a pentadactylous or mammalian type.
(*b*) Reversion to a heptadactylous or reptilian type.
(*c*) Reversion to duplicity of the series of phalanges or selachian type.

2nd group—heterogenic polydactyly. This alone is then monstrous. The author, in giving this classification, recognises that it can only be accepted if Albrecht's theory should prove to be capable of verification by sufficiently definite facts.

Melde's case (XXIX.) is one of polydactyly with absence of the tibia on both sides, and presents several points of great interest. The child had seven toes on each foot, and six digits on each hand. There was no evidence of heredity. The elbow could not be flexed on either side to more than an angle of 90° on account of the existence of a pyramidal-shaped piece of bone which was situated in the coronoid fossa of the humerus. (This point is interesting in connection with the observation of Dwight and others alluded to in the report in this *Journal* for 1893.) There does not appear to have been any peculiarity about the lower end of the humerus itself. In the lower extremity the patella was absent, as also the tibia, which was represented by a strong fibrous band, and the fibula was bent into a crescentic shape. The condition was the same on both sides. As regards the digits themselves, the thumb was double on each hand, and all four thumbs had three phalanges. (This adds another to the scanty list of trimerous pollices, for which see this *Journal*, vol. xxvi. pp. 100 and 440.) The additional toes were internal to the great toe, and that which was nearest to it was possessed of three phalanges. (This would seem to be a case of division, partial in its nature, of the foot.) A full account of the muscles, &c., and a list of cases, completes this most interesting observation.

Bédart (XXX.) describes a good case of hereditary ectrodactyly. The grandfather, August Faurie, who was himself deformed in the manner to be described, had four children. Three of these, who were deformed, produced eighteen children, of whom eight were deformed and ten normal. The transmission of the deformity took place more readily through the female line, all of this sex being affected, two in the second generation and eight in the third. One of these was born with a twin of the opposite sex who was unaffected. In the subjects examined by the author, the feet are forked and bifid, being reduced to their marginal digits, which are separated from one another by a cleft. The other digits are reduced to their metatarsals, which are more or less developed. In the hand, on the contrary, the ectrodactyly affects the marginal digits, only leaving the third and fourth metacarpals with one or more phalanges. The individuals in question are all intelligent and skilful with their hands.

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XXVII. Bardeleben, K. v. "Massenuntersuch ub. Hyperthelie beim Männe," *Verh. d. Anat. Gesellsch*, 1893, s. 171.

XXVIII. Blanc, I., "Etude sur la Polydactyly chez les Mammifères," *Soc. Linn.* de Lyon, 1893 (*Bibl. Anat.*, 1893, p. 82).

XXIX. Melde, R., "Kind mit Beiderseit Defekt d. Tibia u. Polydactylie an Händen u. Füssen," *Inaug. Diss.*, Marburg.

XXX. Bédart, "Ectrodactylie Quadruple," &c., *Bull. de la Soc. d'Anthorp*, Paris, 1892, p. 386.

# Notices of New Books.

## RECENT WORKS ON THE NERVOUS SYSTEM.

*Handbuch der Gewebelehre des Menschen*, Zweiter band, Erste hälfte. By A. Kölliker. Sechste Auflage. Leipzig, 1893.

*Le Système Nerveux de l'Homme*, par A. van Gehuchten. Louvain, 1893.

*Neue Darstellung vom histologischen Bau des Centralnervensystems.* By R. y Cajal. *Archiv für Anatomie*, Band vi. Leipzig, 1893.

*Ueber das Verhalten der Neuroblasten des Occipitallappens bei Anophthalmie und Bulbusatrophie, und seine Beziehungen zum Sehact.* By O. von Leonowa. *Archiv für Anatomie*, 1893, Band vi.

*Zur Frage ueber das Verhalten der Nervenzellen zu Einander.* By A. S. Dogiel. The same *Archiv.*

*Beiträge zur feineren Anatomie des Kleinhirns und des Hirnstammes.* By Hans Held. The same *Archiv.*

*Preliminary Observations on some Changes caused in the Nervous Tissues by Reagents commonly employed to harden them.* By Henry H. Donaldson. Reprinted from *Journal of Morphology*, vol. ix. Boston, 1894.

*Sylvische Furche und Reilsche Insel des Genus Hylobates.* Von W. Waldeyer. *Sitzungsb. der Königl. Preuss. Akad. der Wissench.* zu Berlin, 19th March 1891.

*Das Gibbon-Hirn.* Von W. Waldeyer. *Intern. Beiträge zur Wissensch. Medicin*, Band 1.

*Alte und neue Probleme der Entwickelungsgeschichtlichen Forschung auf dem Gebiete des Nervensystems.* Von H. Strasser. Reprint from Merkel and Bonnet's *Ergebnisse der Anatomie und Entwickelungsgeschichte*, Band 2. Wiesbaden, 1893.

*The Brain of Diemyctylus viridescens*, from larval to adult life. By Susanna P. Gage. Reprint from the *Wilder Quarter-Century Book.* Ithaca, N. York, 1893.

New books and memoirs on the nervous system follow each other with great rapidity.

The discovery by Golgi of the method of examining the minute structure of the nervous system by treating it with solutions of bichromate of potash and nitrate of silver has given an immense stimulus to the study of its histology. Several of the works whose titles are given above display in almost every page the application of this method to its investigation. Many additions to our knowledge of the course of the nerve-fibres, of the processes of the nerve-cells, and of the relations of the fibres to the cells have been recorded.

The first part of the second volume of the new edition (the sixth) of Kölliker's well-known *Handbuch* treats of the elements of the nervous system—of fibres and cells—of the spinal cord of Man and other vertebrates, of the medulla oblongata, of the origin of the cranial nerves, of the pons, crura cerebri, and cerebellum. The part abounds in original observations and drawings, in the preparation of the material for which Golgi's method has been extensively employed. The student will find in it a most useful and instructive handbook to the subject.

Professor van Gehuchten of Louvain has for some years been engaged in histological study, and many of his memoirs have appeared in *La Cellule*, the periodical conducted by Professors in the University in which he holds the Chair of Anatomy. Amongst these his papers on various matters connected with the structure of the nervous system have attracted attention. In the course of lectures which he delivers in the University the nervous system receives especial attention, and he has now published a series of thirty-eight lectures on the subject, abundantly illustrated with 525 drawings and diagrammatic representations of the objects. The descriptions are clearly written, and furnish the student with an excellent summary of the present state of knowledge.

Ramon y Cajal's article in His and Du Bois Reymond's *Archiv* is a statement in German, based on his memoir in Spanish in his Nuovo concepto de la Histologia de los centros Nerviosos referred to in our number for July 1893. It contains, however, additional observations and illustrations, and furnishes us with an account of the most recent opinions of this eminent histological inquirer into the minute structure of the nervous system. He gives many illustrations of the paths of conduction of nerve impulses, of the transmission of these from one cell to another, through contact of collaterals of the axial cylinder of one cell with the protoplasm processes and cell bodies of another. The probable path of the stimulus in a cell which possesses both kinds of processes is cellulifugal in the axial cylinder process, and cellulipetal in the protoplasm process.

The same number of the *Archiv für Anatomie* contains articles by O. v. Leonowa, A. S. Dogiel, and Hans Held on the anatomy of various parts of the nervous system.

Professor Donaldson's observations on the influence of reagents on the nervous tissues refer chiefly to the effects of hardening fluids, especially the effects of solutions of bichromate of potash and of alcohol on the weight, the volume, and percentage of solids in the brain. Most of the observations were made on the brains of sheep. Under the action of bichromate of potash the brain increases in weight and volume, the greatest increase being during the first 24 hours; after the first two weeks the increase is comparatively insignificant. The gain in weight is greater the fresher the brain, absence of pressure, and a low percentage of salts in the solution; it is made less by a temperature of 38 C. The general action of alcohol, as has indeed long been known, is to decrease the weight and volume of the brain. The higher the percentage of alcohol the more rapid and greater is the loss of weight. Zinc chloride causes a loss of weight almost as great as from alcohol. Solution of nitric acid, sp. gr. 1·42, causes little change. After hardening in bichromate of potash, alcohol produces more or less loss of weight. The human brain in its reactions to the same agents resembles the brain of the sheep.

Professor Waldeyer's two memoirs on the Anatomy of the Brain of Hylobates, as would naturally be expected, are important contributions to our knowledge of this organ in the long-armed Anthropoid Apes. The second and longer of the two has, in addition, a personal interest, for it is the article which Waldeyer wrote for the memorial volume published in commemoration of the completion by Virchow of his 70th year.

Professor Strasser's article is a review of some of the more noticeable problems bearing on the development of the nervous system, and of the more recent literature thereon.

The memoir by Susanna P. Gage on the brain of *Diemyctylus viridescens* is a study of this organ in various stages of development. It is stated that in its embryonic, young larval and adult stages it resembles the brain of other Urodeles in corresponding stages. This brain is also compared with those of Amia and Petromyzon. In writing the memoir the author has adopted the peculiar terminology of Burt C. Wilder, which has not yet been accepted by anatomists on this side of the Atlantic.

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*Experiments Illustrative of the Symptomatology and Degenerations following Lesions of the Cerebellum and its Peduncles and Related Structures in Monkeys.* By Professor David Ferrier, M.D., and Dr W. Aldren Turner. Printed in the *Proceedings of the Royal Society of London*, November 30, 1893.

THE authors record the symptoms, temporary and permanent, following total and partial extirpation of the cerebellum, and section of

its peduncles, and the degenerations so induced, also the effects of destruction of the tubercles on the posterior surface of the medulla oblongata, and the degenerations resulting therefrom, together with some observations on the central relations of the 5th cranial nerve. Special reference is made to the similar researches of Luciani and Marchi.

The most noteworthy features of complete extirpation of the cerebellum were the extraordinary disturbances of station and locomotion, and the long continued and apparently persistent unsteadiness of the trunk and limbs on muscular effort. From the first, absence of tonic flexion or contracture of the limbs, retention of great and apparently unimpaired muscular strength, as evidenced by the firmness of the grasp of the hands and feet, and the agility in climbing, and the presence, with ultimate exaggeration, of the knee jerks, were noted. There was no impairment of the general or special sensibility or disturbance of the organic functions.

The symptoms observed after extirpation of a lateral lobe, after the first tumultuous disturbance of equilibrium had passed off, were similar to those observed after complete extirpation, with the important difference that they were confined to the limbs on the side of lesion. Except in one case, where it was only present to a slight extent, there was no impulsive tendency to rotation.

Extirpation of the middle lobe, including antero-posterior division, produced, in general, the same symptoms as were observed in connection with removal of the whole organ and of the lateral lobe, but they did not affect one side more than the other, and were more pronounced in the head and trunk than in the limbs.

The symptoms following section of the cerebellar peduncles were similar to those occurring after removal of the lateral lobe, the chief difference being the greater tendency to roll round the longitudinal axis towards the side of lesion, whichever peduncle was cut.

Destruction of the clavate and cuneate nuclei caused temporary disturbances of attitude and gait, but there was no affection of cutaneous sensibility.

The degenerations following removal of the lateral lobe of the cerebellum, or section of the superior peduncle, showed that this structure contains an efferent tract to the opposite red nucleus and optic thalamus, and an afferent tract, which appears to be the cerebellar termination of the antero-lateral ascending tract of Gowers.

Lateral lobe extirpation, or section of the middle peduncle, was followed by diminution of the transverse fibres of the pons Varolii on the side of the lesion, and atrophy of the cells of the nucleus pontis on the opposite side.

Lateral lobe extirpation, or section of the inferior peduncle, demonstrated the existence of an efferent tract to the opposite inferior olivary body, and of an afferent tract to the cortex, chiefly of the lateral lobe.

Extirpation of the middle lobe occasioned no degeneration in the superior, middle, or inferior cerebellar peduncles, but was followed by

degeneration and sclerosis of the tract which passes from the vermiform process to Deiters' nucleus—the "direct sensory cerebellar tract" of Edinger.

The authors were unable to confirm Marchi's statements as to the existence of a direct efferent cerebellar tract in the spinal cord, or of degeneration in the anterior nerve roots, mesial fillet, or posterior longitudinal bundles, after cerebellar extirpation.

In two cases of lateral lobe extirpation, however, they obtained degeneration in the anterior and lateral columns of the spinal cord respectively, in the position indicated by Marchi. In the case in which there was a marginal degeneration in the anterior column, the nucleus of Deiters, on the same side, was implicated; while in that in which degeneration in the lateral column was present, there was a lesion of the tegment of the pons, involving the nucleus of the lateral fillet. The same degeneration was induced by lesions specially made in the lateral fillet.

Destruction of the clavate and cuneate nuclei was followed by degeneration, on the one hand, through the restiform body into the cerebellum; and, on the other, through the internal and middle arcuate fibres to the opposite interolivary layer and mesial fillet. This latter structure was traced to the anterior quadrigeminal bodies and optic thalamus. Owing to lesion of the roots of the 5th cranial nerve during some of the experiments, they were led to make special investigations on its central connections. Degeneration and sclerosis of the so-called "ascending root" were traced as far as the 2nd cervical nerve, after section of the sensory division, and atrophy of the so-called "descending root" was observed after section of the motor division. They were unable to confirm the existence of a direct cerebellar root to this nerve.

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*The Pathology of the Vermiform Appendix.* By T. N. Kelynack, M.D. London: H. K. Lewis, 1893.

*Om Appendicit.* By K. G. Lennander, *Nordiskt Medicinskt Arkiv.* Band 111. Stockholm, 1893.

During the last few years much attention has been given to the appendix vermiformis, both in its anatomical and surgical relations. In this country Mr Treves has made important contributions to the subject in his work on the Surgical Treatment of Typhlitis. Messrs Lockwood and Rolleston published in this *Journal* in October 1891 a valuable article on modifications in its arrangement, and Dr Struthers has given during the present winter, in a paper in the *Edinburgh Medical Journal*, an account of his observations on this rudimentary structure.

Dr Kelynack's work was published some months ago. It was prepared as a thesis for graduation as M.D. in the Victoria University,

and is published with the permission of the Council. The earlier chapters are occupied with an anatomical description of the appearance, position, structure, and contents of the appendix, whilst the later ones refer to its diseases and their surgical treatment. The clinical aspect of the subject is abundantly illustrated from cases which occurred in the Manchester Royal Infirmary. Numerous figures are introduced into the text, and in an appendix a most copious bibliography of the subject is published. It is a work which we may regard as redounding to the credit of its author.

The article on Appendicitis, by Professor Lennander of Upsala, appears in a *Journal* which is the organ of publication of a large proportion of the best medical and surgical literature of our Scandinavian colleagues. It is edited by the distinguished anatomist, Professor Axel Key of Stockholm. Professor Lennander has had a large experience in the treatment of affections of the appendix, and his memoir is compiled from observations on 69 cases of appendicitis, of which 68 were operated on, and 5 cases of ileus. It would be out of place in this *Journal* to analyse the results of his surgical work, but in connection with this subject we call attention to his article, and the more so because these Norse archives of medicine are somewhat out of the range of reading of practitioners in this country.

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*Weitere Beiträge zur Craniologie der Bewohner von Sachalian—Aino, Giljaken und Oroken.* By A. Tarenetzky. St Petersbourg, 1893.

*Beiträge zur Physischen Anthropologie der Aino.* 1. Untersuchungen am Skelet. By Dr Koganei. Tokio, 1893.

Between twenty and thirty years ago Mr George Busk and Dr Barnard Davis obtained with much difficulty a few specimens of the skulls of the people of Yesso. Since that time Virchow, Kopernicki, and Taranetzky have collected a much larger number of specimens, and have published important memoirs on their characters. The last-named author, whose original memoir appeared in 1890 in the Memoirs of the Imperial Academy of St Petersburg, having obtained additional material, communicated last year to the same Academy a second memoir on the subject.

Dr Koganei is the Professor of Anatomy in the Imperial University of Tokio, and has published in the *Mittheilungen der medicin. Facultät der Kaiserlich-Japanischen Universität zu Tokio*, a portion of his work on the anthropological characters of the Ainos. The first part is devoted to the consideration of the skeleton, more particularly the skull, and contains a most laborious series of descriptions and measurements. His collection, the largest which has yet been formed, contains 166 examples, all of which, with the exception of a single Sachalian-Aino skull, are from the island Kunashiri: 89 of these skulls are associated

with more or less complete skeletons. As a rule, the Aino skull, like the skeleton, is bigger than that of the Japanese, though the cranial capacity is not quite so great, 100 to 104·8. The mean capacity in the men was 1462, in the women 1308 c.c. Of 156 skulls, the length and breadth of which were measured, 25·6 per cent. were dolichocephalic; 64·7 per cent. were mesocephalic; 9·6 per cent. were brachycephalic. Of 155 skulls in which the length and height were measured, 1·3 per cent. were chamæcephalic; 32·9 per cent. orthocephalic; 65·8 per cent. hypsicephalic. The memoir must be referred to for further information. We may congratulate Dr Koganei and the University of Tokio on this important contribution to the anthropology of this interesting aboriginal people.

Journal of Anatomy and Physiology.

# A RESEARCH INTO THE HISTOLOGICAL STRUCTURE OF THE OLFACTORY ORGAN. By JOHN WAINMAN FINDLAY. (PLATE XIII.)

(Conducted in the Physiological Laboratory, Glasgow University.)

IN the summer of 1893, at the suggestion of Professor M'Kendrick, I investigated the above subject, the study of which, though for a time neglected, in our country at least, has since Golgi disclosed his results, and the methods by which he attained them, become full of interest. For the proper elucidation of my theme I have used nothing but absolutely fresh tissues. I studied the different structures mainly in mammals, but also in some fish and the frog, and herewith beg to submit the result, showing wherein my observations corroborate, supplement, or differ from those of previous investigators.

*The olfactory organ* may be divided, briefly, into three parts: *a*, the epithelium for receiving the impression of odours; *b*, the nerves of transmission; and *c*, the central organ or bulb, to which the odorous impressions are carried by the conducting apparatus. The first and a portion of the second part are found in the mucous membrane, which has received the name of "olfactory." This mucous membrane is recognised by a peculiar colour, the pink of the other parts giving place here to a brownish-yellow or almost black in the sheep, and to a yellowish colour in the dog: it has a peculiar gelatinous transparent appearance, and is more succulent-looking and thicker than the non-olfactory mucous membrane. In birds no peculiarity is recognisable by the naked eye. In amphibians it exists as an elevation on the wall of the simple nasal passage, while in the fish a very complicated organ is formed. We have,

first of all, a tough fibrous capsule, so that in the dog-fish the olfactory organ can be easily separated from its connections, and maintains after removal its original form. Inside there are very numerous folds of mucous membrane, with very little connective tissue between, attached to a median septum, and openings leading into the cavity are present to allow of the ingress and egress of water.

The olfactory epithelium presents the same characters in all the members of the vertebrata. It is made up of two distinct kinds of cells: the supporting, which are placed superficially in a single layer; and the olfactory of Max Schultze, which are situated lower down, and are many rows deep.

*The supporting cell* all through is in form cylindrical. Coming from above downwards, it gradually narrows and forms a waist above the nucleus. When it reaches the nucleus, which is large and oval, it gradually widens again, and immediately beneath the nucleus quickly tapers to a fine process. Very rarely is the cell top seen evenly: as a rule it is uneven or rounded, from adherent secretion I feel sure, and not from the presence of cilia, as some writers state. The part of the cell above the nucleus is very granular, and is distinctly striated, the striation being due to the arrangement of the granules in rows, as many as three, four, and five rows being quite easily seen. In individual cells I must say that I cannot see any pigment, but in sections through the mucous membrane in the kitten this part of the cell did not take on the logwood stain, but showed quite distinctly a brownish-yellow coloration. Professor Babuchin describes "a longitudinal striation due to fine olfactory nerve fibrils, embracing the large supporting cells and thus reaching the surface," which I have not succeeded in making out. "I have been able to satisfy myself," says Babuchin, "that this striation is not to be regarded as the optical expression of the surrounding olfactory cells. Moreover, it does not affect the whole thickness of the cell, but is limited to the surface" (see Stricker, vol. iii. pp. 207, 208, and 212). It seems to me that, perhaps, in this matter Babuchin has deceived himself, as no one has confirmed his observations; and we now know from Golgi's researches that the olfactory nerves terminate, not by embracing the supporting cells, but in the

deep processes of the olfactory cells, as Max Schultze shrewdly suspected. Below the oval nucleus of the cell there is a small quantity of protoplasm, which shows few and very fine granules. Continuous with the tapered end is a long process, three and even six times the length of the cell itself. It is cylindrical in form, and has depressions and projections on its surface, caused by the pressure of the olfactory cells round about it. Some of these processes give off minute branches quite soon, or continue downwards a good distance before doing so, while others, after descending to a considerable depth, form cone-like expansions, from which several branches proceed, and these may rebranch two or three times before we finally lose sight of them. This cone-like enlargement may be small, with clear protoplasm, or it may be large and granular. The protoplasm of the processes is clear, and without granulation. Exner and Martin describe these processes as communicating, and forming a network throughout the extent of the membrane, underneath the epithelium; but such communication I have never seen, and don't believe to exist. "The inner half of the cells in question," says Babuchin, "is not so uniform as the external, yet I very much doubt the statements, made by several authors, that they consist of branching processes. They exhibit a great variety of forms, and we may represent these halves as more or less thick cylinders, composed of a soft and transparent mass, in which the round bodies and granules of the olfactory cells are everywhere embedded. Folds thus originate, the borders of which, sharper than the remaining substance, project, giving rise to the appearance of figures that simulate the processes of authors. It is very remarkable that the internal process presents a different appearance under the influence of many reagents. If, for example, the epithelial cells of the Proteus be treated with Müller's fluid or with iodised serum, and be then placed for a short time in diluted glycerine, all traces of the transparent substance vanishes, and the above-mentioned folds make their appearance in the form of branched processes" (see Stricker, vol. iii. p. 208). I cannot agree with Babuchin in his description of these processes as thick cylinders, nor with his view that the branching of them exists merely in the minds of some authors; and I must mention that in all my specimens, whether

examined fresh in salt solution, fixed in osmic or chromic acid and then mounted, or fixed and then stained, these deep processes were seen to branch and otherwise behave as I have already described. These supporting cells are everywhere surrounded by the olfactory cells, which is well brought out by treating the surface of fresh mucous membrane with silver nitrate.

*The olfactory cell* is fusiform or spindle-shaped, and at the lower end, surrounded by very little protoplasm, is a large round nucleus. Above the nucleus the protoplasm forming the spindle is granular. From either end of the cell there springs a process. The upper one is cylindrical in form, and straight and short, or undulating and long, according as the cell itself is placed superficially or deeply, and the process has to insinuate itself between the surrounding olfactory cells for a longer or shorter distance before finally reaching the surface by passing between the supporting cells. In the frog this process bears a bunch of fine cilia, while in all mammals it has a rounded end, is without cilia and projects a little bit beyond the supporting cells. On it there are seen spindle-like enlargements, either from pressure of the fusiform bodies, or from the chemical action of the reagents, and with very high powers a continuous fine fibre can be seen running through all these enlargements. From this, Babuchin supposes the existence of two substances—this internal fine fibre not acted on by chemicals, and an external sheath which is affected by them. These enlargements, as indeed the entire olfactory cell, are best seen in specimens stained with chloride of gold. The lower or deep process, on the other hand, is very sinuous in its course between the cells, as it makes its way downwards or inwards. It tapers from the cell, is very much thinner than the external process, and presents on its surface little nodes or varicosities.

Max Schultze was the first to describe these as the true olfactory cells, and did so from the action exercised on them by chloride of gold, which stains pre-eminently nervous structures, leaving in successful preparations other structures unstained or differently stained. Specimens stained with chloride of gold then show the protoplasm of the olfactory cells, and both their deep and superficial processes dyed of a crimson-lake colour,

while their large round nucleus is hardly stained at all and stands out pale. The supporting cells have neither their protoplasm nor their nucleus stained by this method, and thus, by contradistinction, the olfactory cells are seen with perfect delineation (see fig. 1). A somewhat similar reaction is got by Golgi's nitrate of silver method. In this case the bodies and processes of the olfactory cells are stained almost a jet-black colour, while their nucleus is unstained and remains a brownish-yellow like the rest of the tissue, including the supporting cells (see fig. 2).

"Besides the supporting and the olfactory cells, another kind exists," says Professor Babuchin, "in the proteus and triton, and perhaps also in many other animals, which are likewise intercalated in the epithelial layer, and which call to mind the forked cells of Englemann. They are in immediate contact, by their central extremity, with the sub-epithelial layer, and here frequently break up into very short fibrils. Their peripheric extremity does not reach to the surface of the epithelial layer, and is either conically pointed or branched. Their form, moreover, is very variable, so that in the proteus, for example, we meet with cells that, owing to their ramification, are very similar to the multipolar nerve cells" (see Stricker, vol. iii. pp. 209 and 210). I have not had the opportunity of examining either the proteus or the triton, but in none of the animals that I did examine did I see anything warranting the description of more than two forms of cells, viz., the supporting and the olfactory.

I have been unable to see "in the boundary of the epithelium and the connective tissue the protoplasmic network of cells having nuclei, and termed 'basal cells,'" which Professor M'Kendrick describes in his Text-Book of Physiology, vol. ii. p. 575. I feel sure that in many cases the appearances seen are deceptive, for I have observed the duct of a Bowman's gland, immediately it escaped from the epithelium, turn a right angle and run horizontally, creating an appearance strongly suggestive of a basement membrane, but quite easily allocated to its proper position by a careful examination. In the dog-fish the epithelium is nicely finished off, so to speak, by a very regular arrangement of the olfactory cells at the base of the epithelial layer, which is very marked when seen under a low power. I

saw to most advantage in the kitten the epithelium resting on a layer of dense connective tissue, in which were several elastic fibres and a very large number of capillaries.

*The Glands of Bowman.*—Filling up the space between the epithelium and the periosteum is a large number of tubular glands, very closely arranged. There are no collections of lymphoid tissue here as in the non-olfactory portion. The glands are simple, tubular, without pullulations or processes in the sheep, cat, or dog, and pursue a very tortuous course from the moment they leave the epithelium, so that, in sections carried vertically through the mucous membrane, we merely or mainly see these glands in transverse section. Near their extremities they are lined with large spheroidal cells, which are very granular, and contain a goodly-sized nucleus. Further up the cells become more polygonal in shape and less granular, while just beneath the epithelium and among the cells of the epithelium—that is, in the duct—the cells are cubical in form and much smaller. A basement membrane is described by Hoffman, but Babuchin expresses his inability to see such, and says that the appearance of a membrane is caused by the contour line of the connective tissue in contact with the epithelium of the glands. So far as I have gone, I have been unable to see any basement membrane in the duct portion of the gland, and am confident that no such membrane exists; but deeper down, at the fundus and above it, the appearance of a basement membrane in some cases is quite distinct. The nuclei can be seen bulging out the line of the tube wall in some, while in others the small cells forming the basement membrane are visible, with the glandular cells resting on them. The duct opens at the bottom of a funnel-shaped depression of the membrane, but the lining with cubical cells ceases whenever we pass out from among the olfactory into the supporting cells. Flask-shaped glands are found in the frog. Between the glands, and filling up the space from the epithelium to the periosteum, is fine areolar tissue, in which are round, spindle, and stellate connective-tissue cells. Blood-vessels are also seen, and numerous nerves cut in longitudinal and transverse section, which are remarkably prominent in specimens stained with chloride of gold. In the eel there are no glands, but

instead numerous round cells, mixed up with wavy fibres of connective tissue. In the dog-fish, scattered through the connective tissue beneath the epithelium, and in some cases filling up the greater part of the folds of mucous membrane, are numerous round or oval bodies, possessing a sheath of broad wavy fibres of elastic and connective tissues, and in many particulars looking exceedingly like a tendon in transverse section. Radiating from a central pillar, and directed to and joining with the circumference, are numerous strands of fine fibres, which branch and unite with one another, forming an intricate network. These strands or septa are scantily studded with small round and oval cells. The spaces between the septa are filled with a granular matter, in which I can distinguish no structure. In a few cases cells are seen, of the same order as those on the septa, in the granular matter in the interspaces, but in all probability these cells have nothing to do with the granular matter, and may rather be explained by the presence of another septum further down in the section which does not come into focus. The septa are much finer than those in a tendon, and no stellate cells can be seen in the granular matter (see figs. 5 and 6).

*The Olfactory Nerves.*—The conducting apparatus of the olfactory organ is represented by the so-called olfactory nerves, which ramify in the connective tissue beneath the epithelium between the glands. Fresh and prepared specimens show nerve bundles, in which can be recognised medullated nerve fibres, and running alongside of them, mixed up with them, and in by far the greater preponderance, are nerve fibres like cylinders, showing only a single contour, while at varying distances can be seen oval nuclei occupying the whole calibre of the fibre. These nerve fibres are said to be peculiar to the olfactory region. They have no medullary sheath, but are axis cylinders, with a distinct nucleated sheath more distinct than that of the fibres of Remak. These nerves differ from those of the sympathetic system in possessing nuclei less frequently, and in not having them applied to the surface of the fibre, as is the case with the latter. They pursue a very sinuous and undulating course. This description, which is a corroboration of that of Max Schultze, is objected to by Professor Babuchin. "I am unable to agree," he says, "with the statement of this observer (Max

Schultze) that the olfactory nerves contain primitive nerve fibres, which are constructed on the type of those of Remak, that is to say, of a nucleated sheath of Schwann and fibrillar contents. So far as my observation has extended, however, the fasciculi, whether they are provided with a sheath or not, consist in all animals of extremely fine fibrils kept in position by a finely granular mass. In some animals nuclei are seen in addition, disposed in regular rows between the fibrils, in consequence of which the whole fasciculus is divisible into secondary fasciculi, destitute of a sheath. The sheath of the primitive fasciculi cannot represent the sheath of Schwann, but is rather to be compared, from a morphological point of view, with the neurilemma, with which also its peculiarities and structure may perhaps agree. I may also remark in addition, that I was unable to satisfy myself that the primitive fibre fasciculi in many animals, especially in Plagiostomata, possess any sheath at all. The history of the development of the peripheric nervous system suggests that the olfactory nerves are to be regarded as embryonal structures, that remain persistent at the second grade of their development, whilst the fibres of Remak attain the ultimate stage. The nuclei found between the fibrils of the olfactory nerves are for the most part true cells. They are not unfrequently fusiform, and in this case adhere, by means of their fine processes, very firmly to the nerve fibrils" (see Stricker, vol. iii. pp. 210 and 211). In spite, however, of the above argument of Babuchin, I feel that I have described accurately what I saw, and have tried to represent the same in fig. 3, where, to my way of seeing, the primitive nerve fibres appear most distinctly to possess a nucleated sheath. The olfactory mucous membrane is very richly supplied with nerves, which branch and re-branch as they approach the base of the epithelium, expanding like a fan. These individual nerve fibres, or the few that may go together, now run either obliquely or horizontally beneath the epithelium, and then enter among the olfactory cells by penetrating in a vertical fashion. They then, though continuing their course upwards, do so in an extremely sinuous manner, winding round and between the fusiform bodies of the olfactory cells. Both medullated and non-medullated nerve fibres are seen penetrating the epithelium. I have been

able to follow a medullated fibre almost to the base of the supporting cells, and think that it is not at all unlikely, as Babuchin suggests, that these medullated nerves make their way between the epithelial cells, and terminate on the surface with free extremities. I cannot trace the non-medullated nerves so far outwards, but have seen them breaking up into fine fibrils among the lowest of the olfactory cells (see fig. 4). Babuchin considers it to be highly probable that sensibility and smell are communicated by separate nerves, and so suggests that the medullated impart simple sensation to the mucous membrane, including the epithelium, while the olfactory nerves or non-medullated alone have to do with smell. There is no difficulty at all to my mind in believing this, and I think that now there can be no doubt that the olfactory nerves are prolonged into the olfactory cells. That this is so is shown by the peculiar action of gold chloride, which stains pre-eminently nervous tissues and structures. With it the deep and superficial processes of the olfactory cells were stained of the same colour as the nerves themselves, while the rest of the tissues, including the supporting cells and nuclei of the olfactory cells, remained unstained. It is further proved, though I have never actually traced the nerve fibres or fibrils into the olfactory cells, by the action of Golgi's silver nitrate on this membrane. Golgi's method stains only nerve cells and naked nerve fibres, and by means of it the olfactory cells, with their deep and superficial processes, alone show any reaction, the nucleus and the supporting cells remaining, as in the gold chloride method, unstained. Thus I am enabled to agree out and out with Golgi, after testing his methods, when he says that the olfactory nerve fibres find their origin in the olfactory cells of the Schneiderian membrane, which are therefore to be regarded as peripheral nerve cells, and terminate in the arborisations occurring in the olfactory glomeruli.

*The Olfactory Bulb* is the central organ, to which odorous impressions are carried by the conducting apparatus or olfactory nerves. In the centre of the bulb, but not extending along the olfactory tract, is a cavity, lined with squarely-shaped ciliated epithelium. Surrounding this is a small quantity of neuroglia. Next we come to the "medullary ring" of white matter, in

which numerous medullated nerves, destitute of a sheath of Schwann, are chiefly seen cut transversely in vertical sections, and longitudinally in sections carried from one side to another of the bulb. Then comes what is termed the "nerve cell layer," in which is seen a large number of small neuroglial cells, and a good many large nerve cells, which are mainly conical or pyramidal in shape, very like the pyramidal cells found in the cerebrum, with their apices pointing towards the centre of the bulb, and with their bases directed towards the layer of the glomeruli or spherules. These cells are exceedingly granular, and may possess as many as three or four nuclei. There are also in the deeper part of this layer a few nerve fibres, which have not yet lost their medullary sheath. This layer is described in books as two, namely, a deeper layer without nerve cells, called the "granular layer," and a more superficial, with the mitral nerve cells, termed "the nerve cell layer," but there really is no division between them to necessitate such a description. Next we find the glomeruli, which form an irregular layer two or three deep. They are round or oval-shaped bodies, granular in appearance, and, with ordinary methods, show no structure under the microscope. They are separated from one another by bands of non-medullated fibres, and also by neuroglia, containing small neuroglial cells. Vessels may be seen coursing between the glomeruli, and in certain sections these bodies appear flask-shaped, from the non-medullated nerves escaping from them giving the appearance of a neck to the flask. External to the glomeruli, on the under surface, there is a layer of non-medullated or olfactory nerve fibres, placed almost vertically, which pass immediately through the apertures in the cribriform plate. Surrounding the other surfaces of the bulb, and mixed up with very little neuroglia and a few vessels, is a thick layer of non-medullated fibres, coming from the glomeruli placed all round, but which to escape must make their way downwards, interlacing with one another till they reach the under surface, when they at once sever their connection with the bulb. Cover-glass preparations of the bulb show several small bipolar cells, which are nucleated and exceedingly granular. They possess a thinner and a thicker process: the latter is very finely fibrillated, and breaks up into branches

"In the torpedo," says Babuchin, "it may be demonstrated that the glomeruli are beset externally with very small cells, some of which are bipolar, whilst the majority are multipolar. One of the processes of these cells is sometimes smooth, and runs towards the tractus olfactorius, where it becomes invested with medullary substance. The other processes are at first thick, but subsequently break up into an infinite number of branches, which penetrate the spherical corpuscles. In the bipolar nerve cells the more delicate process passes into the tractus olfactorius; but the other, which is of distinctly fibrillar structure, penetrates into a spherical body, where it breaks up into extremely fine fibrils" (see Stricker, vol. iii. p. 214). I have been unable to see the glomeruli as beset with these small nerve cells, and believe, as I have previously stated, that they are surrounded only by neuroglia and neuroglial cells. Still, I think I have seen bipolar cells at the margin of a spherule, but not actually applied to its surface, by means of Golgi's method, though Golgi himself alone describes the mitral nerve cells. By means of cover-glass preparations, I was also able to make out some very large cells, which are four or even six times the size of the small nerve cells, and two or three times the size of the mitral nerve cells. They are exceedingly granular, and possess a single small nucleus, but, so far as I can see, are devoid of processes. They are very variable in form, and may be round, oval, polygonal, or polyangular. What function they serve, and from what part of the bulb they come, I am unable to tell, as I have never come across any of them in my sections (see fig. 7). By using Golgi's nitrate of silver method, the relations of the different parts to one another come out with great clearness. In vertical sections no staining at all is seen in the situation of the medullary ring. But in the nerve cell layer, the large multipolar nerve cells, which are for the most part pyramidal in shape, have both themselves and their protoplasmic processes stained black, standing out prominently against the yellow background. They are in greatest numbers towards the external part of this layer, while the rest of the layer in some cases is almost entirely filled with naked axis cylinders which are making their way to the medullary ring, a short distance from which they become invested with a medullary sheath, and cease to show any reac-

tion to the silver nitrate. These axis cylinder processes come from the apices of the mitral cells, and give off several branches, which may re-branch once or twice again, and form free arborisations in this layer, but there is no indication of any communication between these branches. From the bases and sides of the mitral cells several processes come off, which are directed towards the layer of the glomeruli, and which branch and re-branch a great many times, forming a most intricate network (see fig. 8). The majority of these branches from the mitral cells then penetrate from all sides into—or rather constitute by coming together from all sides and dividing into still finer branches—the spherical bodies or glomeruli. These glomeruli are made up of a conglomerate of naked nerve fibres, which, after branching and re-branching and intertwining with one another, arrange themselves into a single trunk, form the neck of the flask, and cease to give the black colour from the action of the silver. All the branches from the nerve cells don't enter or form the glomeruli, but ramify in the deeper parts of the nerve cell layer, and here form free arborisations.

In these preparations I am also able to make out (which are not mentioned by Golgi) large nerve cells, similar to the mitral nerve cells, between the glomeruli, sending branches, on the one hand, into the glomeruli, and, on the other, axis cylinder processes towards the medullary ring.

*Summary of Results arrived at in the investigation.*—My description both of the olfactory and supporting cells in the main corroborates the original investigation of Max Schultze. I differ from Babuchin, however, in banding myself with those authors who describe the deep processes of the supporting cells as branching. But I do not believe, as Exner does, that the deep processes of the supporting cells communicate so as to form a basal network. No more can I believe—especially in the light of the peculiar reactions got with gold chloride and silver nitrate—with Exner, that the olfactory cells are only a less developed condition of the columnar. I am, indeed, most firmly convinced that the so-called olfactory cells really are olfactory, and have to do with smell, while the columnar cells are merely supporting, and take no part in the reception of odorous impressions. I have been unable to see the longi-

tudinal striæ—presumably fine nerve fibrils—which Babuchin describes in connection with the supporting cells.

I describe two kinds of cells in the olfactory epithelium, and have not seen the "intermediate cells" of Professor Babuchin.

I am entirely doubtful of the existence of the cuticular lamina, with the olfactory and epithelial cells projecting through its apertures, which was described by Brunn. I have been unable to see the "basal cells" on which the olfactory epithelium rests, as described by Professor M'Kendrick.

My account of Bowman's glands corroborates that of Babuchin and others. I am at one with the statement of Hoffman that a basement membrane exists at the fundus of the gland, and cannot agree with Babuchin in defining the appearance seen, as caused by the contour line of the connective tissue in contact with the epithelium.

I describe, so far as I am aware for the first time, peculiar bodies found in the olfactory mucous membrane of the dog-fish.

The conclusions I have arrived at on the appearance of the olfactory nerves, viz., that the primitive fibres possess a nucleated sheath, and afterwards split up into fibrils, are substantially the same as those of Max Schultze, and differ from the findings of Babuchin.

I have been successful in following both medullated and non-medullated nerves into the olfactory epithelium, and am perfectly certain that the real olfactory nerves end in the olfactory cells, and in no other way, while the medullated nerves may end freely on the surface.

My description of the olfactory bulb agrees with that set down in the last edition of *Quain's Anatomy*, with an exception or two. I have seen, only in cover-glass preparations of the bulb however, large cells devoid of processes, presumably nervous, not mentioned in *Quain*. Babuchin describes in the torpedo the glomeruli as beset with small bipolar and multipolar cells. No one has corroborated this, and I am confident that such is not the case, in mammals at least. No bipolar cells are described in *Quain*, but in a cover-glass preparation I have seen bipolar cells similar to those Babuchin describes, and also with Golgi's method, but not applied to the surface as Babuchin states. My

results with silver nitrate corroborate those of Golgi, but I have discovered in addition that these mitral cells are present not only in the nerve cell layer, but also between the glomeruli.

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## EXPLANATION OF PLATE XIII.

Fig. 1. Vertical section through mucous membrane of the sheep, treated with chloride of gold (Ranvier's method), × 650*d*, it shows the bodies and processes of the olfactory cells deeply stained, while the supporting cells and the nuclei of the olfactory cells are unstained.

Fig. 2. Vertical section through mucous membrane of the sheep, stained by Golgi's method, × 650*d*. The silver has only stained the bodies and processes of the olfactory cells, while the supporting cells and the nuclei of the olfactory cells are unstained.

Fig. 3. Vertical section through olfactory mucous membrane of the frog, stained with gold chloride, × 650*d*, showing, under the epithelium, numerous non-medullated nerves, presenting here and there the nuclei of their sheath.

Fig. 4. Vertical section through olfactory mucous membrane of the sheep, showing only the lowest of the olfactory cells, stained with gold chloride, × 960*d*. *c*, medullated nerve fibre. *d*, non-medullated or olfactory nerve fibres. *d'*, olfactory nerve fibre breaking up into fine fibrils. *e*, olfactory cells with varicosities on their deep or internal processes.

Fig. 5. Transverse section through peculiar bodies in the olfactory mucous membrane of the dog-fish, × 76*d*. *a*, *a'* round bodies. *b*, broad wavy fibres of connective and elastic tissue, mixed up with areolar tissue and connective-tissue cells.

Fig. 6. Portion of *a'* in fig. 5, × 460*d*. *a*, septa radiating from a central point studded with oval and round cells. *b*, granular matter in the spaces. *c*, sheath of broad wavy fibres. *d*, broad wavy elastic fibres and connective tissue.

Fig. 7. Nerve cells from olfactory bulb of sheep, cover-glass preparations, × 650*d*. *a*, bipolar nerve cells showing a thin process, and a thicker one which is finely fibrillated. *b*, large, irregularly shaped cells, apparently devoid of processes.

Fig. 8. Mitral nerve cells from the nerve cell layer of the olfactory bulb, stained by Golgi's method, × 650*d*, showing axis cylinder processes giving off collateral branches, and the dendritic processes branching again and again, and forming arborisations.

# ON THE URINOGENITAL AND BLOOD-VASCULAR SYSTEMS OF A RABBIT POSSESSED OF A SINGLE KIDNEY. By JAMES HARRISON, *Lecturer on Biology, Battersea Polytechnic Institute.* (PLATE XIV.)

DURING the practical work of the biological class at the Battersea Polytechnic Institute, my attention was recently called to the fact that one of the rabbits obtained for dissection had only one kidney. On informing my master, Professor Howes, he kindly placed the laboratory and literary resources at the Royal College of Science at my service.

I first found that, with regard to its kidney, the specimen fell into four of the categories proposed by Brown[1] in his (the most recent) classification of this class of variation: that is, (1) there was but one kidney, the right; (2) that was displaced, being more posteriorly placed than even the left kidney when normally present in the same species; (3) it was a floating kidney, having a well-developed and complete mesonephron, though it did not hang loosely in the peritoneal cavity;[2] and (4) it was of an abnormal shape.

*Blood-vessels.*[3]—Macalister remarks that the "irregularities of the renal arteries are the commonest varieties met with among the abdominal vessels;" and Brown associates the variation in size and number of the kidneys with these as determining factors.[4] In the animal under notice there is an agreement, with regard to the renal arteries, with what generally obtains in cases of single kidney in man. The renal artery proper (*a.r′* of fig. 2) was larger than usual, and there was a supernumerary renal artery (*a.r″*) arising from the right common iliac, close to its base. Brown mentions that in his case "the

[1] "Variations in the position and development of the kidneys." Macdonald Brown, *Jour. Anat. and Phys.*, vol. xxviii. p. 194. (See also this paper for further references to literature.)

[2] *Loc. cit.*, p. 203.

[3] Macalister, *Jour. Anat. and Phys.*, vol. xvii.

[4] *Loc. cit.*, p. 201.

order of the structures entering the hilum was slightly altered the artery lying in front of the vein," and this arrangement I also found in the rabbit. It is the more interesting, since both Macalister and Brown mention the origin of a supernumerary renal from the common iliac artery; and the former quotes a case, described by Otto, of one springing from the right common iliac entering the left kidney. An interesting example of this kind of anomaly is figured by Eisler[1] with reference to a case of three renal arteries on the left side, the most posterior arising at the point of bifurcation of the aorta, the anterior giving a branch to the adrenal body, the kidney on the right side having its normal arterial supply. Johnson also refers to the fact that "in some instances" the renal arteries "arise even from the common iliac or hypogastric artery," and that "the two last-mentioned origins are usually associated with an unusual position of the kidney."[2]

Besides the extra renal artery there were other abnormalities. As is well known in the rabbit, the ovarian arteries usually spring from the aorta somewhat posteriorly to the inferior mesenteric artery, and pass outwards to the ovary. In the specimen under consideration, however, these arteries (*a.o*) both arose anteriorly to the latter,—that on the left side from the aorta, posteriorly to the point of origin of the anterior renal artery, and that on the right side from the base of the renal artery itself. This latter condition has been seen in numerous autopsies.[3] The right ovarian artery, after leaving the renal, took a sharp curve backwards as far as the anterior edge of the kidney, and then forwards to a more anterior level than that of its point of origin; it then passed outwards and backwards, supplying not only the ovary, but also the largely developed mesonephron, and ended, as an important branch, above the bladder and ureter, a little to the left of the median line. In the figure the mesonephron is omitted, and consequently the

[1] Eisler, *Anomalie des Art. renalis bei Verlagerung des Niere.—Anat. Anzeiger*, 1889, p. 465..

[2] *Todd's Encyc. of Anat. and Hist.*, vol. iv. pt. i. p. 286.

[3] Simpson, *loc. cit.*, vol. ii. p. 684. See also Young "On the termination of mammalian aorta," and Robinson on "Abnormalities of the venous system, and the relation to the development of the veins;" *Studies in Anatomy*, vol. i., Owens College, Manchester.

posterior branches of the ovarian artery, in order to show the blood-vessels dorsad of them.

Each common iliac artery branches into an internal and external iliac, and in connection with these we meet with other anomalies. On the left side (fig. 2) the internal iliac passes dorsad of the external iliac vein, but just before doing so gives off the branch forming the superior vesicular artery (*a.v.s*), which is distributed to the bladder and furnishes the only arterial supply to that viscus. The condition is closely akin to that shown in Young's figure of the vessels of the wombat for the opposite side, and differs strikingly from the condition of the beaver, which he figures (*op. cit.*, pl. vii.) as a type of the Rodentia. On the right side the artery answering to the internal iliac also passes dorsad of the external iliac vein, but it remains unbroken for about an inch of its course, when it quadrifurcates into (1) a smaller obturator, passing to the pubic region; (2) a larger hæmorrhoidal, distributed to the region of the vagina and to the vestibule; (3) a still larger internal iliac, or a continuation of the original slightly reduced in calibre; (4) a small artery passing to the vertebral region. This division takes place immediately above the bifurcation of the right internal iliac vein. The internal iliac vein then passes backwards, giving origin on the outer side to the gluteal and sciatic arteries, on the inner to the ischiadical, rectal, or anal branches, and to the pudic artery. Hence the distal portions of the urinogenital apparatus are supplied by three arteries,—the superior vesicular on the left side, the hæmorrhoidal or inferior vesicular, and the pudic artery on the right side. The mesosacral artery had its normal origin from the dorsal surface of the aorta a little anterior to the bifurcation. With reference to the veins I experienced a greater difficulty, owing to injury on removing the intestine. However, as all the veins caudad of the kidney, and as far cephalad of it as the point of junction of the great renal vein with the vena cava were preserved, all the parts likely to be affected by the abnormal conditions were present. On referring to the figures, it will be seen that the renal vein (*v.r*), which is very large, joins the vena cava almost as far forwards as is usual, about two inches from its exit from the kidney. This vein not only serves as a carrier of blood

from the kidney, but also receives two of the median dorsal veins (see fig. 2), the right ovarian vein and the right ilio-lumbar. The union of the ilio-lumbar vein with the renal is of common occurrence on the left side in rabbits, but in this animal that condition is realised on the right, the only side possible, while its fellow on the left side joins the vena cava in the normal position.

The mid-dorsal arteries all spring from the aorta, none from the renal artery. The origin of the renal artery is less anteriorly situated than the junction of the vein with the vena cava, the artery being only about an inch in length (fig. 1) from its origin to its entry into the kidney; and the supernumerary artery passes almost directly outwards from the base of the common iliac to the kidney, a little anteriorly directed, if any deviation from the lateral. As seems to be common in these cases, the supernumerary artery enters the kidney posteriorly to the head of the ureter, the vein immediately anteriorly to it, and the renal artery in front of that. The capsular artery arose from the aorta. The inferior mesenteric artery had its origin half an inch posterior to the left ovarian, instead of anterior to it. The ilio-lumbar arteries had their usual origin from the common iliac and the left vein its usual point of junction, but, as has been noticed, the right ran forward dorsad of the kidney and joined the renal vein near to the point where the ovarian also joins it, the junctions of both being between the points of union with it of the dorsal veins which it receives.

*Reproductive Organs.*—Beumer and Brown both regard the condition of single kidney as almost inseparably connected with defects in other organs, more especially the reproductive ones, and the case herein recorded tends to support their conclusion. On cutting down to the pubis, I found the usual median ventral ligament to the bladder, and, on each side, the *round* ligament, looking like a gubernaculum, passing back to the points of insertion in the peritoneal pit. What struck me particularly was the close and strong attachment of this ligament on the left side, it being attached much more closely and strongly than on the right; and also the strong connections of parts of its approximately distal extremity with the median ventral ligament of the bladder, and the connective-tissue investment of that

viscus generally, and to the dorsal wall. The ligament on the right side, as just mentioned, was much more loosely attached, and, owing to the direction of the single ureter, or of the position of the kidney in the mid-area, the bladder must have been in danger of being displaced to the left. The bladder was collapsed, but a diligent search revealed the fact that not only was there no trace of a second urinary aperture, but also no trace whatever of a second ureter. The ovaries and their largely developed round ligaments looked like undescended testes. On cutting open the vestibule, a small pimple appeared in the position normal to the apertures of the uterus masculinus and prostate glands of the male, but no aperture was visible by means of a hand-lens. Below it, however, was an oval opening, in a position corresponding exactly with the opening of the vagina into the vestibule; and such it proved to be. Between the vestibule and rectum was the customary mass of cysticercoids, and this was removed as carefully as possible. There was evidence of a trace of the base of the uterus masculinus in the papilla before mentioned, and also of a vagina in the oval opening about a quarter of an inch below it; but there were no uteri or Fallopian tubes. On dissecting behind the vestibule, a small sac was found, into which the oval aperture led. This sac was about three-eighths of an inch in length, and had no anterior opening: it ran forward on the dorsal surface of the vestibule, more or less distinctly, as rather indefinite-looking tissue, for a little more than half an inch. This, which was unquestionably the vestige of a vagina (fig. 1*a*), alone represented the genital ducts. To be quite satisfied, in the face of such abnormal conditions, as to the sex, —the ovary being the only really essentially female organ developed,—a small portion of the genital gland was stained and prepared for microscopic examination. Sections of this showed clearly that the gland was an ovary of typical structure.

*Liver.*—It may be well to notice that the caudate lobe of the liver, being free from the right kidney, had lost to a considerable degree the cup-like arrangement of its posterior surface; and that the thin edges of the lobelets protruded into it, quite changing the character of its surface.

# ON THE LONG SENSORY ROOT OF THE CILIARY GANGLION AS FIGURED BY CLOQUET. By W. RAMSAY SMITH, M.B., C.M., B.Sc., Rhyl, North Wales.

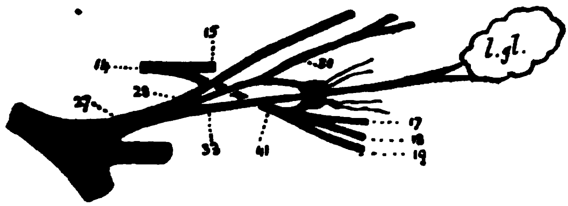
THE roots of the ciliary ganglion are usually described as three:—(1) The long sensory root from the nasal branch of the ophthalmic; (2) the short motor root from the inferior division of the third nerve; (3) the sympathetic root from the cavernous plexus. The second and third of these do not come within the scope of this communication.

With reference to the first of these, the long sensory root, it may now be taken as the accepted view that, although it is apparently a branch of the ophthalmic division of the fifth nerve, it is not really so. Whether the ciliary ganglion is a secondary outgrowth from the Gasserian ganglion, as a sympathetic ganglion is from a spinal root ganglion, or whether the ciliary is the ganglion of the radix longa of segmental value that has become fused secondarily with the fifth nerve, is not of prime importance so far as regards my present purpose. One may take for granted that the long root of the ciliary ganglion, keeping up the communication between it and the Gasserian, need not necessarily go by way of the ophthalmic nerve.

Some time ago, when examining the plates in Cloquet's Anatomy[1] illustrating the distribution of the cranial nerves, I observed that one of the figures showed an abnormal arrangement of the roots of the ciliary ganglion; and it is to this arrangement that I would now draw attention. Plate 182 differs from all the others in the book, and also from other books, as regards the course of the long root of the ganglion. In order to show the variation, I have drawn accurately from the plates the pertinent parts of the illustrations. Both of Cloquet's plates are drawn by his artist from nature, and evidently with great care. Plate 178, which shows the normal arrangement, is drawn from a dissection of the head of a man

[1] *Manuel d'Anatomie Descriptive du Corps Humain*, par Jules Cloquet. Paris, 1825.

about thirty years old, showing the distribution of nerves in the orbital cavity. Plate 182, which depicts an abnormal arrangement, is drawn from a dissection of the head of a man twenty-




FROM PL. 178.

two years of age, showing the arteries and nerves of the face and orbit. A glance at the two sketches shows the abnormality, viz., the long root of the ciliary ganglion proceeding, not by way of the nasal branch of the ophthalmic, but *direct from the Gasserian to the ciliary ganglion.*

In view of the mode of development of these ganglia, this is an abnormal arrangement that one might well expect to find. I have searched in vain for any record of it, and I have never


FROM PL. 182.

seen an example of it in the dissecting-room. That it actually occurred in Cloquet's case there can, I believe, be no room for doubt—the artist evidently faithfully represented what he saw; and one need not hesitate to draw attention to this as a rare and interesting abnormality.

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## REFERENCES TO DRAWINGS.

*N.B.*—The figures and names of parts are copied from Cloquet's plates and descriptions.

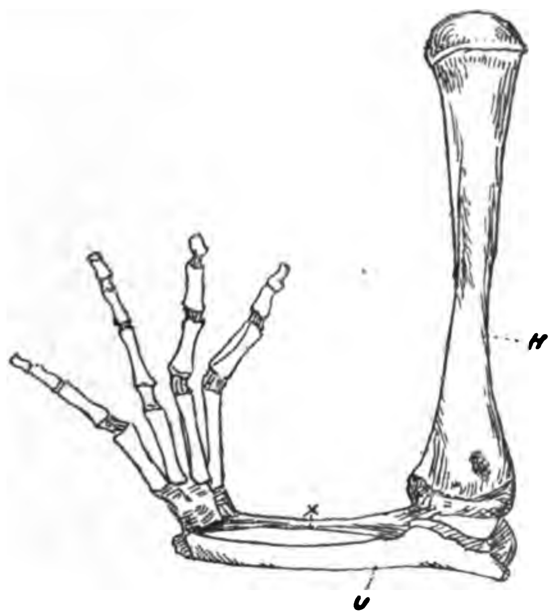
Plate 178.—14, third nerve, dividing into 15, the superior branch,

and 41, the inferior branch. The inferior branch divides into three parts :—first, the short root of the ciliary ganglion; second, a branch, 17, to the internal rectus, and a branch, 18, to the inferior rectus; third, a nerve, 19, to the inferior oblique. 27 is the ophthalmic branch of the fifth nerve dividing into three :—first, 28, the frontal; second, 30, the nasal, which gives off the long root to the ciliary ganglion; third, 33, the lachrymal to the lachrymal gland.

Plate 182.—60, third nerve, dividing into 61, the superior branch, and 62, the inferior branch. 84 is the frontal, and 97 the lachrymal branch of the ophthalmic nerve. 90 is the nasal nerve.

THREE CASES OF CONGENITAL ABSENCE OF THE WHOLE OR PART OF A BONE. By C. C. BAXTER TYRIE, M.B., C.M. Edin., *Demonstrator of Anatomy, Yorkshire College.*

THE first case was one of complete absence of the radius on both sides, occurring in a full-term fœtus. The child was well developed, and, with the exception of the forearm and hand, well formed. The hand, from which the pollex was completely absent, projected outwards at right angles from the end of the forearm, which projected slightly beyond the articulation.




Right Upper Limb. *H*, humerus; *U*, ulna; *x*, fibrous band replacing radius.

Subsequent dissection showed an entire absence of the radius, its place being occupied on both sides by a band of fibrous tissue.

The carpus, which consisted of five elements, was swung round and articulated with a facet on the outer aspect of the

ulna. This facet was encrusted with typical hyaline cartilage, and the joint was provided with a synovial membrane, thus forming an adventitious joint of the highest type.

The second case, which also occurred in a fœtus, was similar to the preceding, but not complete: the lower third of the radius on the left side was replaced by a fibrous cord. The thumb was present, and the hand had been swung round on to the external aspect of the ulna: the carpus was complete.

Third case.—For this I am indebted to Mr Littlewood, F.R.C.S. The patient was two years of age, and had been brought to the infirmary here because he could not walk. The left foot was considerably everted; and although the general contour of the leg was good, the fibula was found to extend down the leg only a third of its length, where it ended in a point from which a fibrous band could be felt stretching down to and becoming lost in the region of the external malleolus.

The first two cases beautifully illustrate the prowess of Nature as a surgeon. The result aimed at after excision of the whole or a considerable part of the lower end of the radius, is to bring round the hand on to the ulna, and, through the medium of the subsequently developed fibrous bands, form a serviceable articulation. All this had been done in these cases; and, in addition, a facet had been formed, cartilage deposited, and the original wrist synovial membrane modified to suit the new conditions, or a new one developed. The fibrous band present in each case, replacing the whole or part of the bone, is probably the remnant of the original perichondrium, and, by its subsequent contraction, is the chief element in the production of the deformity.

Cases of suppression of the whole or part of the radius are far from uncommon, and it is difficult to see why it should be the radius that is suppressed and the ulna retained.

The radius is a remarkably constant bone throughout the animal kingdom; while the ulna, on the other hand, is extremely variable, sometimes present, sometimes only partially so, and in other cases completely absent.

Two views have been advanced as to the production of these deformities. The first is, that the deformity is due to the environment, the most common factor being an abnormal nar-

rowing of the developing amnion. The symmetry of the deformity in the first case tends to negative this theory. The second view, which is the more applicable in the majority of cases, is that these conditions are due to a lack of "formative materials or forces, or both."

Two examples of regression of osseous and cartilaginous tissues to fibrous, viz., the processus gracilis of the malleus and the cartilaginous representative of the os centrale of the wrist, are normally found in the human body, and many of the bones of lower animals are only indicated in Man by fibrous bands. A comparison of the statistics of absence of the long bones of the limbs shows that the radius is the most variable, and the fibula next. Is it probable that this indicates that a modification of the limbs is being evolved in which there will be only one bone in the forearm and leg?

# ON THE MORPHOLOGY OF THE TENDO-ACHILLIS.

By F. G. PARSONS.

IN dissecting the muscles of a Canadian beaver some little time ago, I found, as Meckel states, that the two bellies of the gastrocnemius remained separate down to their insertion in the os calcis. I also noticed that the two tendons of the muscle and that of the plantaris were twisted round one another like the strands of a rope, so that the tendon belonging to the internal head passed superficially to that of the external and to the plantaris tendon, and was inserted externally to both of them. Further down, the plantaris became superficial to the external head, and passed in a groove in the back of the tuberosity of the calcaneum to be continued into the plantar fascia and flexor brevis digitorum. This arrangement is shown in the accompanying figure.

I then examined a series of other mammals, including the kangaroo, many rodents, the chevrotain, the dog, the ichneumon,

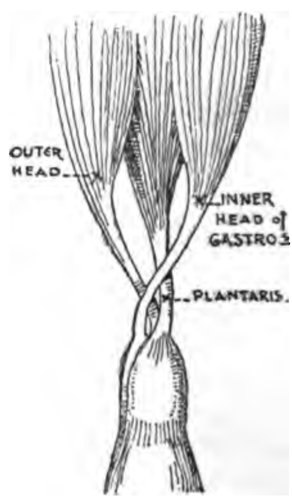



FIG. 1.—Tendo-Achillis of Beaver (*Castor canadensis*).

and the macaque, and found that, although the two tendons of the gastrocnemius were fused, they could, with little difficulty,

be separated, and that when this was done the same arrangement was evident.

In birds, the two tendons unite just before they reach the tarso-metatarsus, but I could not satisfy myself that the same crossing exists.

In lizards, among reptiles, the inner head of the gastrocnemius is quite separate, and crosses over the outer head to reach the external side of the foot.

On carefully examining the tendo-Achillis of the lower mammals it will be noticed that the four parts of which it is composed—the two heads of the gastrocnemius, the soleus and the plantaris—have undergone a twist of half a circle. This I was able to prove by separating the different parts in a puppy, after which I cut through the ankle-joint and turned the foot round until the toes pointed backwards; when this was done, the two tendons of the gastrocnemius and that of the plantaris became untwisted, and lay parallel to one another.

The same twist may be seen in the tendo-Achillis of Man, though it is modified by the great development of the soleus as an adaptation to the erect position. If the human tendo-Achillis be carefully looked at, it will be seen that the fibres from the inner head of the gastrocnemius pass obliquely downwards and outwards over the rest of the tendon, to be inserted on its outer side. This arrangement is figured in many textbooks, notably in Henle, but I have not met with any description of it. That the soleus part of the tendon undergoes the same twisting I was made aware of in dissecting a human fœtus of about five months: in it I could distinctly trace the soleus winding round the inner side of the rest of the tendo-Achillis, to be continued into the flexor brevis digitorum in the sole. In a fœtus a little older this connection of the soleus was lost; but it is quite easy, in a 7 months human fœtus, by a little careful dissection, to separate the part of the tendo-Achillis which is formed by the soleus from that formed by the gastrocnemius; when this is done, it will be seen that just before the insertion into the tuberosity of the calcaneum, the outer part of the tendon is formed by the gastrocnemius, while the inner and large part is continuous with the soleus.

I have had the opportunity of examining fœtuses of the horse

and sheep, but did not find that the soleus joined the flexor brevis digitorum, probably owing to the fact that in these animals the soleus is a very rudimentary muscle. On the other hand, the plantaris tendon is continued at quite an early stage

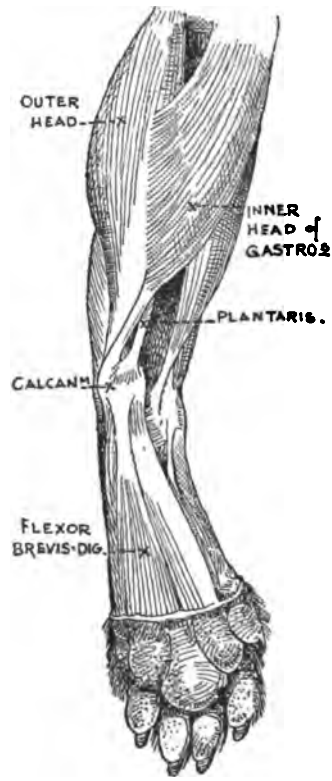



FIG. 2.—Tendo-Achillis of Ruddy Ichneumon (*Herpestes smithi*).

into the flexor brevis, so that in these ungulates the three typical flexors of the phalanges have been converted into two.

This has been done by the suppression of the proximal part of one muscle and of the distal part of another, followed by the junction of the two remaining halves.

In other words, the plantaris, the flexor of the proximal phalanges (corresponding to the flexor perforatus of birds), practically loses its foot portion in the horse and sheep, there being little or no plantar fascia in these animals; while the

flexor of the middle phalanges (corresponding to the flexor perforans et perforatus of birds) retains its foot portion as the flexor brevis, but its leg portion, the soleus, becomes rudimentary. Finally, the plantaris joins the flexor brevis to form one continuous muscle. A stage in this transition can be seen in the beaver, in which, as above mentioned, the plantaris splits into two layers, the superficial being the plantar fascia, and the deep the flexor brevis digitorum.

The rope-like twisting of the four tendons of the gastrocnemii, the soleus, and the plantaris has been described by Dr Murie in the Malayan tapir,[1] but I am not aware that it is known to exist in most mammals, including Man.

Two explanations of this internal twist have occurred to me. The first is the internal rotation which occurs in the fœtal limb by which the dorsal surface becomes the anterior: this rotation occurs above the knee-joint, and therefore would be above the present attachments of the muscles entering into the composition of the tendo-Achillis. There is every reason to think, however, that the vertical separation of these muscles took place before they acquired their present attachments near the knee; in other words, that there were muscles stretching from the ischium to the sole which might have shared to a slight extent in the rotation of the limb. But whether this had any influence or not, it certainly could not account for the 90° of twisting which is found in the adult.

The other explanation that suggests itself is the position of the fœtal limb in utero: the ankle is dorsally flexed and the foot is adducted, so that in the fœtal lamb or horse the two feet are crossed underneath the abdomen. This position of the foot, which is found in a less marked degree in the human fœtus, might account for a still further rotation of the tendon. Whatever the cause may be, it does not seem to act only on the constituents of the tendo-Achillis, for in the other tendons which cross one another on the flexor aspect of the leg and foot it is the internal which crosses superficially to the external. Examples of this are the flexor longus digitorum and tibialis posticus, also the flexor longus digitorum and flexor longus hallucis.

[1] *Jour. Anat. and Phys.*, 1872, p. 163.

Respecting the serial homology of the muscles composing the tendo-Achillis, my dissections bear out the theory that the plantaris is homologous with the palmaris longus, and that the soleus and flexor brevis digitorum correspond to the flexor sublimis digitorum. With regard to the theory that the two heads of the gastrocnemius correspond respectively to the flexor carpi radialis and ulnaris, I made two or three dissections in different mammals to find out where the nerve supply came from. As the internal plantar nerve corresponds in its distribution to the median, and the external plantar to the ulnar, I expected that, on separating these two nerves up to the thigh, each of them would give off the branch to one of the heads of the gastrocnemius. As a matter of fact, I was disappointed to find that the two nerves to the gastrocnemius were connected together in the thigh, and could be traced up as a single cord as far as the great sciatic foramen without being bound up in either of the plantar bundles. From former dissections, however, I am inclined to regard this fact as merely pointing to the comparative untrustworthiness of nerve supply in determining the homologies of muscles.

# MICROCEPHALY AND INFANTILE HEMIPLEGIA. By

ALEXIS THOMSON, M.D., F.R.C.S.E., *Assistant Surgeon, Royal Infirmary, Edinburgh.*

MICROCEPHALY has proved an attractive subject to many observers, and probably few cases have escaped record in some form or other. There are few museums worthy of the name which do not contain one or more specimens, and but few large asylums devoid of a living example of the condition. It may be open to question whether it is wise to add to the list of published cases, but, in view of the want of unanimity in the opinions of those who are authorities, it appears desirable that facts should continue to be collected.

Two fascinating hypotheses as to the etiology of microcephaly were no sooner evolved than they had to be abandoned: Vogt's well-known suggestion[1] that it represents a type of brain inherited from some remote ancestral ape was exploded by Gratiolet,[2] who pointed out that *no* arrest of development could make the human brain more nearly resemble that of the ape than it does in the adult. It has been well said by Giacomini[3] that microcephaly cannot be utilised to favour any theory of man's descent, since it does not represent any stage in the evolution of man. The speculation that microcephaly depended upon a premature synostosis of the cranial sutures had no chance of acceptance when it was found that union of the sutures was deferred rather than premature. As expressed by Giacomini, microcephaly is always neural, never osteal,—*i.e.*, the deformity of the skull is the result of circumstances arresting the development and growth of the brain itself. Although it is a step in advance to have got rid of erroneous theories, we do not possess any definite knowledge of the circumstances to which Giacomini

[1] "Mémoires sur les Microcéphales ou Hommes-singes," Carl Vogt, Genève-Bâle, 1867.

[2] "Mémoire sur la Microcéphalie," Gratiolet, *Journ. d. l. Physiologie de l'homme et des animaux*, Paris.

[3] "Cervelli dei Microcefali," C. Giacomini, 1890.

refers. Klebs[1] places microcephaly in the group of dysplasias connected with the development of the placental circulation and formation of the amnion and allantois: he holds that it is an amniotic malformation in which a hindered extension of the cavity of the amnion interferes with the development of the projecting portions of the body of the fœtus, and that these latter, although properly laid down, are hindered in their later development. It is supposed that in microcephaly the hindrance affects the anterior extremity of the embryo, because the malformation is limited to the skull and brain. The complete closure of the skull and spinal canal prove that there is no fusion of the amnion with the fœtus, such as is believed to account for the group of dysplasias of which anencephaly is an illustration.

That the spinal cord not uncommonly participates in the arrest of development is no refutation of the hypothesis of Klebs, for the defects which have been observed in the cord may be reasonably regarded as secondary to those in the brain. Another, and possibly a correlated, explanation of microcephaly suggests that it originates in a disturbance of the fœtal circulation, by which the blood-vessels destined for the brain segment of the embryo are imperfectly developed. It may be well to bear this view in mind, and to seek for facts which may lend support to, or disprove it. No gross circulatory defects have been discovered in uncomplicated microcephaly: the disproportionate development and growth of the face and external parts of the head, supplied by the external carotid, show that defects of the kind suggested are to be sought for in the vessels supplying the encephalon itself. I shall refer at another part of this paper to the liability to gross vascular lesions exhibited by the cerebral hemispheres of the microcephalic brain; but as these are, unfortunately, by no means peculiar to the latter, too much importance cannot be attached to their bearing on the circulatory origin of microcephaly.

It would appear that the arrest of development which results in microcephaly may occur at different periods of embryonic life, and that different forms or degrees of the condition are met with according to the period at which the arrest of development

[1] "Allgemeine Pathologie," Klebs, 1887.

takes place. According to Marchand,[1] there is no individual type of microcephaly, but an almost continuous series of transition forms from the normal form of the fully-developed humau brain to quite rudimentary conditions. On the other hand, there are transitions to other complicated malformations of the brain which may be associated with diminutiou in size, and which result from some disturbance at a still earlier period of development. It may be associated with or accompanied by other developmental defects, *e.g.*, in the brain, encephalocele, porencephaly, and hdryocephalus; on other parts of the body, *e.g.*, the extremities. The hypoplasia of the brain shown by its small size and diminished weight may affect certain portions more than others. The total weight may be less than one-fourth of the normal. The diminution mainly involves the cerebrum; for although the cerebellum, pons, &c., may be dwarfed, they are so to a less degree. It is commonly observed that the hemispheres do not cover the cerebellum. The cerebrum is not only smaller; it presents also grave morphological alterations. In a case recorded by Allen Star the fore-brain was entirely wanting. In another case recorded by Barlow,[2] the convolutions could not be identified over the greater part of the convexity, and the corpus callosum was absent. In another, described by Kossowitsch,[3] there were no sulci whatsoever. In the commoner forms the convolutions and sulci are excessively simple, and are more or less atypical in their arrangement. The secondary sulci are especially imperfect. The fissures of Rolando and Sylvius, when present, are abnormally steep and open, and exposure on the free surface of the island of Reil is very commonly observed.

The grey matter of the cortex is, as a rule, relatively thick. The ventricles are usually dilated. In many cases the cord is imperfectly developed (micromyelia): the defect chiefly involves the white matter, notably the pyramidal tracts and columns of Goll, and to a less extent the cerebellar tracts and anterior columns. In a case recorded by Kossowitsch,[3] the lateral

[1] "Beschreibung dreier Mikrocephalen-Gehirne nebst Vorstudium zur Anatomie der Mikrocephalie," Felix Marchand, 1889.

[2] Barlow, *Trans. Path. Soc. Lond.*, vol. xxviii.

[3] Barbara Kossowitch, *Virchow's Archiv*, bd. 128, hft. 3.

columns were only half their natural size. The grey matter, which is usually relatively greater in amount than the white, may present a diminution in the number of its cells; this has been especially observed in the anterior horns.

Certain facts tend to show that microcephaly, like many other developmental defects, may be hereditary, or may run in families. Langhans records the case of a microcephalic mother who gave birth to a microcephalic child. In one of the cases I shall describe, a sister was similarly affected.

Epilepsy, idiocy, insanity, and other cerebral disorders are not uncommon in families in which microcephaly occurs; on the other hand, such history may not be forthcoming.

Though entirely congenital, the condition may escape recognition at birth, and may only become evident at a later period, when the facial continues to grow in excess of the cerebral portion of the head and the deformity becomes more evident; on the other hand, the mental phenomena may be the first to attract notice. The life-history of microcephalics presents variations in correspondence with the different degrees of cerebral development, to which reference has been made. They do not usually develop and grow like other children. Most of us are familiar with the feeble physical development of the so-called Aztecs. On the other hand, the smallest microcephalic skull I have seen, viz., one in the collection of the Royal College of Surgeons of England (No. 95A), is said to have belonged to an active male adult 5 feet 6 inches in height. Some may be taught a great deal by education, while, on the other hand, many have not even the capacity of feeding themselves.[1] The majority succumb in early adult life to phthisis pulmonalis. The microcephalic brain is itself predisposed to disease, and paralyses of cerebral origin are by no means uncommon.

The results of surgical interference, and the role of the operation introduced by Lannelongue under the name of craniectomy, do not come within the scope of the present paper. It would

[1] I have watched a family of children of which one was a microcephalic: the latter took an active part in their games or play, but would look on at the others feeding without thinking of helping himself, though physically well able to do so, and when fed by the mother he would swallow so long as food was placed in his mouth. They do not put on flesh like other children, and are certainly liable to tubercular disease.

appear, however, that the improvement obtained is not always maintained.

The specimens I propose to describe consist (1) of the entire head of an uncomplicated case of microcephaly; and (2) of the brain and skeleton of an adult microcephalic who became the subject of hemiplegia in early life. For both specimens, and for their clinical histories, I am indebted to my brother, Dr D. G. Thomson, Superintendent of the Norfolk County Asylum. I am further indebted to Mr Charles W. Cathcart for directions in the preparation of the specimens, and to Professor Sir William Turner for criticism on the description of the brain.

CASE 1. *Microcephalic Head—Clinical History.*—M. H., f., single, aged 29. Height, 5 feet; weight, 7 stone 7 lbs. The youngest of six children, of which the fourth was stillborn and the fifth was a microcephalic imbecile. The parents were healthy, intelligent, steady people; they and their near relatives were free from insanity or allied neurosis. The patient was a fully-developed fine child, born naturally, and seemed all right till the age of 15 months, when she had what was regarded as a fit, from which time she did not seem to grow or develop like their other children. At 2½ years true epileptic convulsions developed, and continued throughout life. She could walk about and use her arms, but was generally feeble; could not articulate or learn to speak, except to imitate sounds and words like a parrot. She was little influenced by training, except to be cleanly in her habits. She was vain about dress, and fond of bright colours and musical sounds. She was admitted to the asylum in January of 1881, and died of phthisis in November of 1892.

The following measurements indicate a moderate degree of microcephaly: it is to be borne in mind that they were made with the head still invested by the soft parts:—

| | |
|---|---|
| Horizontal circumference through glabella and occipital protuberance, . . . | 431 mm. (17 in.) |
| Frontal arc from auditory meatus to auditory meatus, . . . . . . . | 242 mm. (9½ in.) |
| Sagittal arc from glabella to ext. occip. protuberance, . . . . . . . | 242 mm. (9½ in.) |
| Long diameter of face from glabella to chin, . | 102 mm. (4 in.) |

The carotids of either side were injected with carmine, and the latter fixed by injection with lard. The head was then submerged in spirits. The following day the vertex was trephined and the dura opened. A week later the left half of the cranium was removed and the dura reflected. When the brain had sufficiently hardened *in situ*, it was removed for separate examination.

As it was desired to preserve the specimen entire, THE SKULL was not examined in detail. The following facts were, however, observed. The sagittal suture was entirely absent; the other sutures were normal; the parietal arch was generally uneven, being unnaturally concave immediately in front of, and parallel with, the lambdoidal suture, and unusually convex in the region of the eminences.

In *structure* the bone (of the calvaria) is compact, with little diploë; it averages 3–5 mm. in thickness; anteriorly and posteriorly it measures nearly 10 mm.

The *cerebral surface* presents clearly-cut grooves for the meningeal arteries, and is marked to an unusual degree with hollows and projections corresponding to the convolutions and sulci of the hemispheres.

The *dura* was well injected; it presented no abnormality.

The *tentorium* was observed to be attached to the skull posteriorly 10 mm. above the external occipital protuberance.

The *arachnoid* and *pia*, also minutely injected, were for the most part easily reflected, but on the right side, over those convolutions found at the juncture of the parietal, temporo-sphenoidal, and occipital lobes, and over the cerebellum, they were abnormally thin and adherent, and could not be stripped without tearing the subjacent cortex. This adhesion was most noticeable in the region of the parietal eminence on the right side.

Attention was directed to the *cerebral arteries*, which were well filled with injection. They are strikingly small, probably but little larger than those of an infant at birth; at the base they are crowded together because of the limited area available, but they are quite normal in their arrangement. The branches proceeding to the hemispheres are not the same on the two sides. To the left hemisphere (which will be shown to be the more fully developed of the two) the arterial trunks, though fewer in number, are relatively larger, and are more equally and uniformly distributed to the different lobes, while on the right side, beyond a leash of branches occupying the Sylvian fissure, and radiating from it to the adjacent gyri, there are none of any importance.

*The Brain*, after being hardened *in situ*, was removed from the

skull: it is fairly well formed, and measures, from the frontal to the occipital pole, in a straight line, 116 mm. The cerebrum completely overlaps the cerebellum; at the base of the brain, the parts, though small and crowded together, have their normal mutual proportions. The convolutions of the cerebral hemispheres present a characteristic simplicity in their arrangement, being for the most part broad, fully rounded, and separated from each other by wide and deep fissures; there is a relative absence of secondary convolutions and fissures. The two hemispheres differ from each other both in size and in the structural arrangement of parts; the left hemisphere is broader and deeper, its convolutions are larger and better formed, approaching more nearly the normal, except that the parietal and occipital lobes are defectively developed, while in the right hemisphere there are many gross deviations from the normal, more especially in the area corresponding to the junction of the parietal, occipital, and temporo-sphenoidal lobes, which is occupied by a series of narrow, reduplicated convolutions, over which, as has been already described, the soft membranes were closely adherent.

In the *left hemisphere* the *Sylvian fissure* is normal in position and direction; it is 50 mm. in length, the anterior limb 12 mm.; its lips are in apposition, and the Insula is not exposed. The *fissure of Rolando* (R) is identified by its forming the posterior boundary of the frontal lobe; there is no ascending parietal convolution; the upper half of the fissure is represented by an open gap or interval, intervening between the superior end of the ascending frontal convolution and the supra-parietal lobule, and is continuous with a well-marked *intra-parietal sulcus*, which, in its turn, opens into the median fissure a little in front of the *external parieto-occipital fissure*. At the angle of junction between the fissure of Rolando and the intra-parietal sulcus there is a partially exposed eminence of grey cortex, which may perhaps be regarded as the representative of the ascending parietal convolution.

The *pre-central sulcus* is well developed (see fig. 1).

Of the *different lobes, the frontal* is by far the largest and the most fully formed, its different convolutions are well developed and easily identified, both on the orbital and external aspects; the inferior convolution, embracing the anterior limb

of the Sylvian fissure, is the best formed convolution in the entire brain.

*The temporo-sphenoidal lobe* is but little inferior to the frontal lobe in its development; of the three convolutions on its external aspect, the superior is the best formed; it is well defined by the Sylvian and parallel fissures between which it lies, and it is continuous round the posterior extremity of the first-named fissure into the large and well-developed supra-marginal convolution; the middle and inferior are continuous posteriorly with the corresponding occipital convolutions.

*The parietal lobe* is imperfectly and unequally developed; the ascending convolution is not recognisable as such; the intra-parietal sulcus is abnormally open, so that the supra-parietal is separated from the supra-marginal and angular convolutions in a marked degree.

*The occipital lobe* presents the least successful approach to the normal type; its posterior extremity is pointed, and projects well beyond the cerebellum; it is separated from the parietal lobe by a widely open external parieto-occipital fissure (PO); its convolutions are small and ill formed.

In *the right hemisphere*, as has been already indicated, the fissures and convolutions present considerable deviations from the normal (fig. 2).

The *fissure of Sylvius* (S) is short (38 mm.), almost vertical in direction, and its lips are in apposition: the island of Reil is situated at the bottom of the fissure. The anterior limb of the Sylvian fissure leaves the main fissure at a very acute angle, and is 20 mm. in length.

The *fissure of Rolando* is not recognisable as such, but in the position which it should occupy at its upper end there is a fissure 11 mm. long extending into the marginal convolution.

In *the frontal lobe*, which is alone developed on a scale corresponding to that on the opposite side, the ascending convolution is not recognisable; the superior and middle convolutions are continued backwards without interruption into a single broad marginal convolution, which runs parallel with and bounds the median fissure, and terminates at the posterior end of the hemisphere in the pointed extremity of the occipital lobe; the external parieto-occipital fissure (PO) is merely developed to a degree

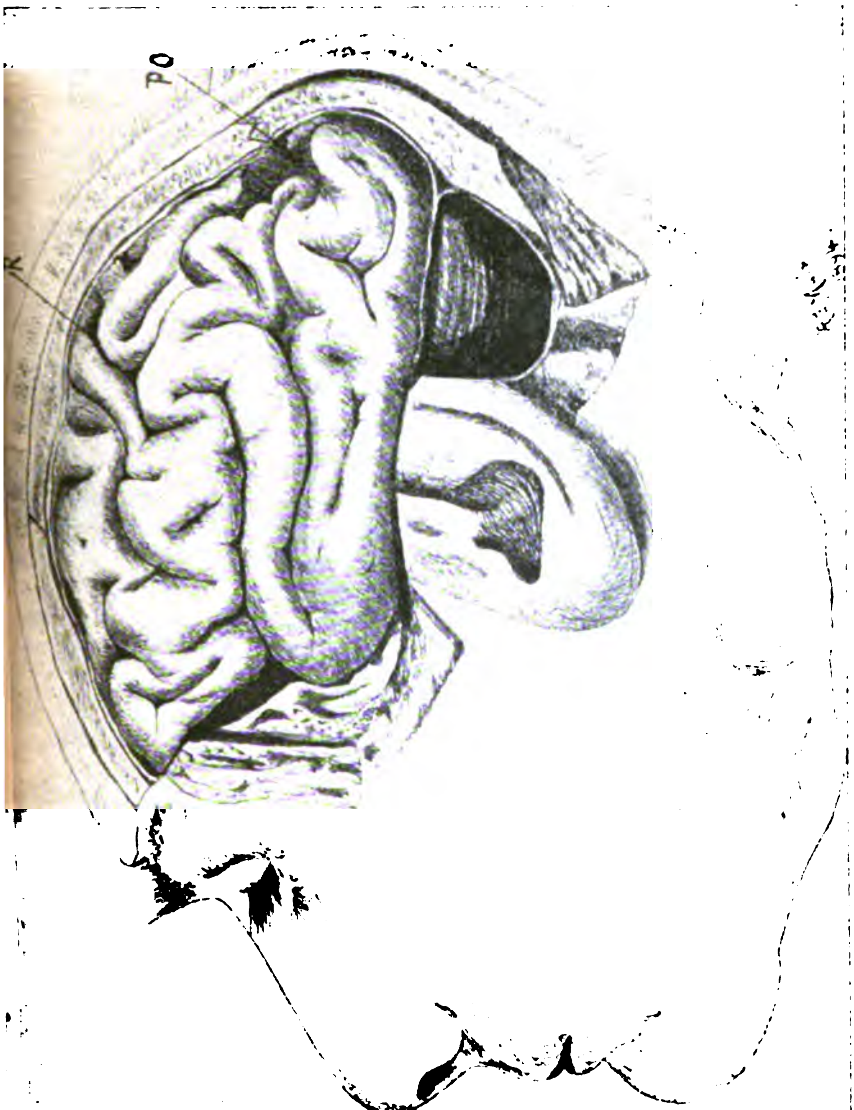



FIG. 1.—Head and left hemisphere of brain *in situ*. This and the other figures are from photographs.

sufficient to indicate where the parietal portion of this convolution ends and the occipital portion begins. Both in this and in the left hemisphere the internal part of the parieto-occipital fissure is deep and vertical in direction. From the posterior end of the occipital lobe, the same marginal convolution may be traced forwards into the inferior temporal sphenoidal convolution, which is large and well formed. The superior and middle temporo-sphenoidal convolutions are smaller in proportion; when traced backwards from the tip of the lobe, they become fused


FIG. 2.—Profile of Right Hemisphere.

together about half way along the posterior limb of the fissure of Sylvius to form a single convolution, which turns round the posterior end of the fissure to become continuous with the inferior frontal convolution. In the triangular area which remains, on the outer aspect of the hemisphere, bounded above, below, and in front by the series of convolutions described, there is, in place of the large, smooth, rounded, somewhat cumbrous convolutions observed in the other parts of the hemisphere, an irregularly arranged group, of small, narrow, miniature or reduplicated convolutions closely applied one to the other, presenting an appearance which is quite characteristic, and which, in its extreme

forms, has been likened to that of the folds in the frill of a shirt. The condition has been described and figured by Giacomini, Ziegler,[1] and others in the brain of microcephalics, and by Professor Sir William Turner in a recent paper in the *Journal of Anatomy and Physiology*.[2] The area occupied by these peculiar convolutions in the present specimen corresponds to the terminal distribution of the middle cerebral artery, and the pia-arachnoid was intimately adherent over the area in question.

*Measurements of Brain (M. H.).*

| | | Mm. |
|---|---|---|
| Maximum length, | | 116 |
| Maximum breadth, | | 80 |
| Greatest horizontal circumference of cerebrum, | | 253 |
| Greatest breadth mid-parietal, | | 80 |
| Greatest breadth of frontal lobes at lower end of inferior frontal, | | 63 |
| Maximum length of hemispheres, | right, | 115 |
| | left, | 116 |
| Greatest breadth of right hemisphere, | | 35 |
| " " left hemisphere, | | 45 |
| Length of hemisphere from most anterior part of frontal to most posterior part of occipital, measured along its superior margin, | R. | 144 |
| | L. | 154 |
| Of this on the left side, the frontal lobe contributes | | 94 |
| " " the parietal lobe contributes | | 33 |
| " " the occipital lobe contributes | | 27 |
| Greatest height of hemisphere, | R. | 63 |
| | L. | 70 |
| Length of cerebellar hemispheres, | R. | 35 |
| | L. | 40 |
| Breadth of cerebellum, | | 68 |
| Height of cerebellum, | | 22 |
| Length of pons, | | 22 |

In reviewing the facts elicited by the examination of this specimen, we may, in the first place, dismiss the altered relations of the brain to the skull as being of little or no importance. In the second place, it was found that the arterial blood supply to the hemispheres was more plentiful and followed the normal lines more closely on the left or better developed side. Whether

[1] Ziegler, "Allgemeine Pathologische Anatomie," 1892.
[2] "Human cerebrum with a remarkably modified fronto-parietal lobe," *Journal of Anat. and Phys.*, vol. xxv., 1891.

the unilateral vascular deficiency bore any causal relationship to the deficiency in development of the corresponding hemisphere, or whether the vascular and cerebral defects were merely the associated result of one common cause, it is not possible to determine. It is not improbable that an exaggerated and localised defect in development such as this brain presented in the triangular area on the right side, to which attention was especially drawn, may be the direct result of an abnormal vascular supply; more than one observer has drawn attention to the fact that the microcephalic brain, during the earlier years of life, is liable to be the seat of vascular lesions (thrombosis, hæmorrhage), more especially affecting the area of distribution of the middle cerebral artery. In the third place, we may refer to the physiological bearing of the peculiarities of conformation presented by the brain: the individual during life could only imitate a limited number of sounds, and yet, although right-handed, we find the left inferior frontal convolution to be by far the best developed in the entire brain: again, while possessed of motor functions not far short of the average, on the right side the ascending convolutions are scarcely represented, and on the left they are very imperfectly developed: finally, we have an altogether disproportionate development of the frontal lobes, while the functions with which they are accredited were only conspicuous by their absence, the individual being a complete idiot from the earliest years of life; the inference is clear enough that the relatively large amount of grey matter in the cortex remained dormant and functionless; this being quite in harmony with what is observed in those individuals who are not idiots.

In view of the more perfect development and normal conformations of the basal and central portions of the encephalon in microcephalics, may we not assume that the cerebral hemispheres play an altogether subordinate part in the energising of the body, and that the basal ganglia, as in the lower orders of the animal kingdom, are mainly responsible for that amount and kind of nerve power which they exhibit?

CASE 2. *Microcephaly together with Hemiplegia, dating from Infancy—Clinical History.*—H. E. A., aged 30, was admitted to the Norfolk County Asylum on the 31st March 1890, suffering from

idiocy, with paralysis. The history, as supplied by the father, showed that she belonged to a healthy family, in which the only taint consisted in a cousin of her mother's having died insane. The patient is the youngest of four children, three sons and one daughter, of which the former are now healthy sane men,—one, however, bears a character for intemperance and indolence. At birth the patient was to all appearance healthy and well formed, and during the first twelve months of her life nothing abnormal, either mentally or physically, was noticed by the parents. She never had any fall or injury. It was only when the child ought to have made attempts at standing and walking that it was found that the right arm and leg were weak; the weakness increased, and the affected limbs became drawn up; the mother remarked that she never stretched herself like other children. So gradual was this weakness of the right side that its date of onset remained obscure, and it was attributed to backwardness until it became very pronounced, *i.e.* when she no longer used the right arm to grasp anything, and could not put the right leg to the ground. She therefore never walked; and even when she sat in a chair, she tended so much to fall to the right side that a recumbent posture soon became necessary. She remained in this posture from this time until her death at the age of 31. Mentally she was backward, and unable to talk; she took notice of things, and appeared to know her parents and brothers one from another.

At the age of three she had the *first convulsive seizure*, of which insensibility and torpor were more prominent features than convulsion. She lay for a long time as if dead; then, after a succession of deep sighing respirations, she gradually regained consciousness.

These "fits" became frequent, and recurred from time to time till the age of 26, when they abruptly and altogether ceased. *Pari passu* with the onset and succession of the fits, the physical condition became worse; the power of movement in the right arm and leg totally disappeared, and they became more and more drawn up and wasted, not growing at the same rate as the limb of the opposite side; the spine became twisted and curved; there was evident paresis of the muscles generally, excepting those of the head and neck, which she could and did move freely. With the left hand she could feebly grasp any toy after feeling about for it, and would always knock it against her teeth. She lay on her back in bed quite helpless. Her bowels only acted once a week with strong aperients. She was very sensitive to touch over the body generally, and screamed on being washed, changed, or handled in any way. She was abjectly dirty in her habits. She made no progress mentally; she never learned to speak a single word, nor could she even express desires by signs. She seemed to notice things, and expressed pleasure at the sight of coloured pictures. She had to be fed with the spoon. From year to year there was little change in her condition: the head, which had always been small, did not increase in size; the trunk and limbs continued to grow until the age of 20, when she attained the maximum height of 129·5 cm. (4 ft. 3 in.). At the age of 30 sores developed

at the points of contact and pressure of the right leg and left thigh, and she was sent to the asylum, where she continued to live for a year. She died in January 1891.

At the *post-mortem examination* there was little worth noting apart from the central nervous system and skeleton. The lungs were free from tubercle; there was a small calculus in the gall-bladder. The descending colon and rectum were enormously distended with fæcal accumulation.

*The Brain*, when fresh, weighed 19 oz.; unfortunately it was placed in spirits, with the result that it became flattened and shrunk considerably, so that the details of its form, and especially its measurements, are only approximately correct. The membranes, except at the site of special lesion, are normal.

*The Brain*, as a whole, is remarkably *small;* the diminution in size specially *affects the cerebrum*, of which the hemispheres are short and narrow, and cover but little more than half of the cerebellum. The latter, medulla, and pons are also small, otherwise they are fairly well developed.

*The cerebral hemispheres* are not symmetrical, the right being larger and better developed than the left; in virtue of this preponderance in size it occupies nearly two-thirds of the convexity, the great longitudinal fissure being correspondingly displaced to the left of the mesial plane.

*The right hemisphere* may be considered in the first place, because it approaches more nearly to the normal; in comparison with the other lobes, *the parietal is very small* and imperfectly developed; it is separated from the frontal lobe by a well-marked vertical transverse fissure, which at its upper end arises directly from the median fissure, while in its lower half it *runs parallel* with and in front of the posterior limb of the *fissure of Sylvius;* this latter fissure pursues an abnormally steep or vertical course; it is also *wide*, and *the island of Reil* is partially exposed. The ascending frontal and ascending parietal convolutions are not definitely marked; the supra-marginal and angular convolutions are most imperfect; the supero-parietal convolution is quadrilateral in form, and bounded below by a short intra-parietal sulcus, which is continued behind into the parieto-occipital fissure.

*The frontal lobe* is relatively *large and well developed;* its antero-posterior convolutions and sulci are easily identified, both on the convex and orbital aspects, and the middle frontal is partially divided into an upper and lower tier.

*The occipital lobe* is *small and flat,* and roughly quadrilateral in outline; it is separated from the parietal lobe by a well-marked external parieto-occipital fissure; its *posterior extremity is remarkably obtuse;* it presents no evident differentiation into convolutions; its outer portion is directly continuous with the inferior temporo-sphenoidal gyrus.

*The temporo-sphenoidal lobe* is *relatively large;* its long axis is more vertical than horizontal, in correspondence with the abnormal course of the Sylvian fissure; there is no distinct separation between its superior and middle convolutions; the inferior, on the other hand, is well defined from the rest of the lobe by a deep middle temporo-sphenoidal sulcus.

*The insula,* so far as it may be seen without dissection, presents no peculiarity.

*The left hemisphere,* as has been partly indicated, differs very remarkably from the right. The great *diminution in its volume* is best appreciated by a comparison of the measurements of the two hemispheres. The alterations in form which it presents are not such as may be ascribed to the micrencephalous condition *per se. The parietal and greater part of the frontal lobes* are represented by *a thin membranous structure* completely and closely folded so as to suggest a resemblance to the frill of a shirt; this layer, which in parts does not measure more than *2 mm. in thickness,* forms the *roof of the dilated lateral* ventricle. There is *no recognisable trace of a Rolandic fissure nor of the ascending convolutions,* which normally form its boundaries, except in so far as these are concerned in the formation of the completely folded membranous layer already referred to. *The island of Reil,* with its five radiating finger-like convolutions, is *completely exposed* on the lateral and inferior aspects of the hemisphere, and is remarkably well developed; posteriorly it is separated from the temporo-sphenoidal lobe by a deep and broad fissure, corresponding in position to the posterior limb of the fissure of Sylvius.

*In the parietal lobe* the only *convolution capable of being*

*identified is the supra-parietal lobule;* in *the frontal lobe* the *superior* and *part of the middle* convolutions are quite distinct, and are fairly well formed; the ascending parietal and frontal convolutions and the inferior frontal are involved in the folded membranous layer occupying the cortex in the situation normally occupied by these convolutions. On the other hand, the *occipital* and *temporo-sphenoidal* lobes are developed similarly to those on the other side, only they are smaller. A minute portion of *the membranous cortex* in the situation of the motor areas was removed and *examined microscopically;* it was found to consist of a fine neuroglia reticulum, in which were embedded numerous small angular and rounded cells and minute colloid particles, and numerous capillaries running through it; there was no trace whatever of the pyramidal ganglion cells characteristic of the grey matter in the region in question, while at the same time it should be stated that the neuroglia or basis-substance stained faintly after the fashion of this tissue in its normal state,—that is to say, there did not appear to be any fibrous tissue of new formation like that met with in the different forms of sclerosis which affect the grey matter. Of white matter, representing the fibres of the corona radiata, there was no trace whatsoever in the situation of the membranous cortex, from which the portion was taken for microscopical examination. The fact may be recalled that, in the common micrencephalic brain, the grey matter is thick out of all proportion to the white matter.

*The corpus callosum*, so far as could be seen without dissection, did not appear to present any peculiarity.

The dilated lateral ventricle was opened into on the left side, and in its floor the *corpus striatum* and *optic thalamus* were seen, and appeared to be normal.

*Resumé* of chief peculiarities :—

1. Diminution in size, especially of hemispheres, which only cover half of the cerebellum.
2. Right hemisphere larger than left, to degree that it occupies two-thirds of convexity.
   The Sylvian fissure open, and exposing a well developed insula.

Frontal and temporo-sphenoidal lobes relatively large and well developed.

Parietal rudimentary; the ascending and postero-parietal convolutions alone developed.

The occipital ill formed and showing little differentiation into convolutions.

3. Left hemisphere dwarfed by microcephaly + special "pathological" lesion, viz., replacement of grey and white matter of the two ascending and the inferior frontal convolutions and adjacent parts by a thin membranous folded layer roofing in the dilated lateral ventricle, and consisting of neuroglia; exposure of a well-developed insula.

It must be conceded that the faulty preparation of this brain diminishes the value of the above observations; they are, nevertheless, of considerable pathological interest. The micrencephaly, though very evident, is moderate in degree and fairly typical; it differs from the one already described in the greater disproportion in the development of the hemispheres of the large brain in relation to the cerebellum and parts at the base; in the presence of the ascending convolutions on the right side, and the greater exposure of the insula on both sides. The chief interest, however, centres in the gross lesion in the region of the motor convolutions on the left side in the second specimen, and its association with a right-sided hemiplegia.

*Measurements of Brain.*[1]

| | Mm. |
|---|---|
| Maximum length, . . . . . . . | 132 |
| " breadth, . . . . . . . | 90 |
| Greatest horizontal circumference of cerebrum, . . | 335 |
| " breadth in mid-parietal region, . . . | 90 |
| " breadth of frontal lobes at lower end of ascending frontal, . . . . . . . | 80 |
| Maximum length of right hemisphere, . . . | 107 |
| " " left " . . . . . | 98 |
| " breadth of right " . . . . . | 55 |
| " " left " . . . . . | 35 |
| Length of hemisphere from most anterior part of frontal to | |

[1] These were made after hardening in spirit; those selected are in the main those employed by Marchand. *Op. cit.*

| | | | Mm. |
|---|---|---|---|
| most posterior part of occipital, measured along its superior margin, | Right, 130 mm. | Left, | 110 |
| Of this, on the right side, the frontal lobe contributes | 90 ,, | | |
| ,, ,, parietal | 22 ,, | | |
| ,, ,, occipital | 18 ,, | | |
| Greatest height of hemisphere, | | | 55 |
| Length of corpus callosum, | | | 50 |
| Length of cerebellar hemispheres, | | | 47 |
| Breadth of cerebellum, | | | 87 |
| Height of cerebellum, | | | 40 |
| Length of pons, | | | 23 |

The *spinal* cord, of which a segment from the cervico-dorsal junction was kindly examined by Dr Gordon Sanders, to whom I am indebted for the following notes:[1]—"*The grey matter* on the left side was fairly normal; on the right side the anterior horn was reduced in size, and its tissue was pale and fibrous; in the antero-external and lateral vesicular columns the nerve cells were scanty; the nerve strands of the posterior root were reduced both in number and in size.

"*The white matter* showed a general increase in the connective tissue of all the columns on both sides, this being much more pronounced on the right. The antero-lateral tract of Gowers was markedly sclerosed on both sides; while, on the right, the direct cerebellar and crossed pyramidal tracts were especially affected, and to a less degree the postero-external column."

## THE SKELETON.[2]

*The skull* is small—the diminution in size specially affects the cranial box; the lower jaw presents a very open angle, the nasal bridge is high, the forehead flat and receding; the vortex is more conical than dome-shaped. The cranium is asymmetrical or scoliotic; the right half is more convex, and is greater in its dimensions than the left; this is also evident at the base; a line drawn from the occipital protuberance through the centre

[1] The segment of cord examined was unfortunately not placed in Müller's fluid until sixty hours after death. The sections, stained after Weigert-Pals' method, were not all that could be desired. As measured from the sections, the antero-posterior diameter of the cord was 6 mm., the transverse diameter 8 mm.

[2] The skeleton and brain are preserved in the Museum of the Royal College of Surgeons, Edinburgh.—*Catalogue*, vol. i. p. 205.

of the basi-occiput and palatal arch is convex to the right; similarly the right auditory meatus is not so far forwards as it is on the left side. This asymmetry of the skull is the result of the pathological diminution in size of the left cerebral hemisphere, to which attention has already been drawn.

The sutures do not differ from those of the normal skull. The flat bones are rather above the average thickness; both tables and diploë are present. The fossæ at the base are remarkably small, while the different bony projections and grooves are unusually well marked. The frontal sinuses, and especially the left, are disproportionately large; the roof of the left sinus is vaulted into the interior of the cranium. The palate, instead of being arched, is broad and horizontal; its constituent bony plates are translucent.

The turbinates are very large and well developed; the nasal septum is markedly deflected to the left. The teeth which remain are encrusted with tartar; the upper incisors override the lower.

*Measurements of Macerated Skull.*

| | Mm. |
|---|---|
| Greatest horizontal circumference, | 411 |
| Transverse arc from meatus to meatus, | 273 |
| Sagittal arc from glabella to foramen magnum, | 290 |
| " " to external occipital protuberance, | 248 |
| Diameter through skull from glabella to occipital protuberance, | 135 |

*The bones of the trunk and extremities* present features which are etiologically associated with a right-sided hemiplegia dating from infancy, together with uninterrupted recumbency for nearly thirty years. Those features connected with the hemiplegia show themselves especially in the bones of the right arm and leg, and to a less degree in the trunk, while those resulting from the recumbency and disuse are common to both sides.

## THE TRUNK.

*The spine* exhibits a type of curvature which has not been described. It could only originate under the conditions present in this case, viz., early hemiplegia and recumbency. It is a scoliosis with rotation; there is no kyphosis nor lordosis, both of which require the erect posture for their development. The scoliosis is primarily lumbar with the convexity to the left; it

gradually tapers off in the dorsal segment; the cervico-dorsal spine is quite straight; there are *no compensatory curves.* In the lumbar curve, rotation of the bodies is well marked, and is of the usual character, viz., the anterior surfaces of the bodies face the convexity of the curve. [It has been stated that the rotation element in scoliosis depends upon the superimposed weight of the head, &c.; its presence in this specimen shows that it is not so.] The individual vertebræ present only a moderate degree of asymmetry; the inter-vertebral discs were thin and imperfectly formed. There is bony ankylosis of the laminæ of the 12th dorsal with the 1st lumbar, and of the 3rd and 4th lumbar; indicating that no movement of the curved portion of the spine took place during life.

*The thorax* is scarcely implicated in the spinal curvature; it is moderately flattened from before backwards.

*The pelvis* presents features of unusual interest; while retaining certain infantile characters, it is of the female type. The bones are thin and wasted to an extreme degree; the flattened portions of the ilia, which approach the perpendicular, are quite translucent, and are equally so on the two sides; they are as thin as writing-paper. The thyroid foramina are very large; the iliac crests do not present the usual S-shaped curve. The pelvic inlet is circular, and is contracted in all its diameters; the cavity is shortened chiefly because of the exaggerated curvature of the sacrum and coccyx; the coccyx projects into the outlet, possibly a result of lying on the back. The sub-pubic angle is abnormally open, being quite 20° above the average. From the measurements given below, it will be seen that the transverse diameter at the outlet is the only one which is greater than the normal, although the general appearance of the pelvis suggests a capacity above the normal.

| Measurements. | Specimen. | Average. |
|---|---|---|
| Conjugata vera, . . | 90 mm. | 108 mm. |
| Left oblique at brim, . | 115 ,, | 125 ,, |
| Right ,, ,, . | 110 ,, | 125 ,, |
| Transverse at brim, . . | 112 ,, | 132 ,, |
| Conjugate at outlet, . . | 65 ,, | 95 ,, |
| Transverse at outlet, . | 120 ,, | 108 ,, |
| Inter-spinous, . . . | 148 ,, | 230 ,, |
| Between iliac crests, . . | 153 ,, | 255 ,, |
| Sub-pubic angle, . . | 120° | 90–100° |

*The Extremities.*—The bones of the extremities are *on both sides* remarkably small, thin, and light; they are deficient in indications of the attachments of soft parts; the long bones possess a fairly developed cortex, inclosing a small amount of spongiosa. Their articular ends and the short bones have an imperfect cortical layer, which can be indented with the finger-nail. The bones of the *paralysed* (right) *side* present the above features in a greater degree, and further exhibit the phenomena of arrested growth. There is considerable *deficiency in length*, and this varies in the different bones. It is most pronounced in the humerus (26 mm. shorter than the left), then in the femur (18 mm.), fibula (17 mm.), radius (16 mm.), ulna (12 mm.), tibia (6 mm.), and clavicle (4 mm.). There is no difference in length in the scapula, metacarpals, metatarsals, or phalanges. *The deficiency in girth* of the bones on the paralysed side is also considerable; in the fibula it is so pronounced that the central portion of its shaft is no thicker than a common wooden match. The shafts of the other long bones are proportionately attenuated, and they all present an exaggeration of their normal curvatures. Lastly, there are a number of alterations in the bones entering into the different joints, which are the result of the acquired deformities. The nature of these deformities is illustrated in the photograph of the articulated skeleton (fig. 3).

*In the upper extremity, on the right side*, the shoulder presents a natural attitude, with the upper arm drawn to the side; the elbow is flexed to nearly half a right angle; the hand is pronated, and flexed to such a degree that the fingers are in contact with the forearm. The thumb is extended and adducted; its tip protrudes on the dorsum between the index and ring fingers. The fingers present a slight degree of flexion of the first phalanx and extension of the second; the third phalanx is either moderately flexed or is in line with the second. *The left upper extremity* does not present any deformity!

*The right lower extremity* illustrates the acme of possible deformity: the thigh is flexed, rotated in and markedly adducted; the leg is acutely flexed and slightly rotated out; the foot is *flexed* and everted. The position of the thigh and prominence of the hip are associated with a complete *dorsal disloca-*

*tion of the head of the femur;* the inferior and inner segment of its head is in contact with the innominate bone above and behind the acetabulum. The head itself is small, of uneven surface, and devoid of articular cartilage. The neck is considerably shortened. The lesser trochanter is large and prominent, and on its posterior aspect there is a smooth convex facet which articulates with a similar facet on the brim of the pelvis, overhanging the anterior and inner edge of the acetabulum. The cavity of the acetabulum is represented by a triangular depression, of which the base is at the cotyloid notch; the floor is rough and uneven, and is devoid of articular cartilage. The area which was in contact with the displaced head of the femur is semilunar in shape, and is situated just beyond the upper and posterior edge of the acetabulum.

The shaft of the femur is twisted on its long axis, so that the apex of the lesser trochanter is directed forwards instead of inwards.

In connection with the extreme flexion of the *right knee-joint,* there are changes in the bones as follows: the articulating portions of the femoral condyles are represented by narrow ridges or crests, which were not in contact with the tibia at all but with the superjacent skin, and they were invested by an imperfect layer of fibro-cartilage; the areas of actual contact with the tibia are located on the superior surface of the posterior extremity of either condyle, and are less than half an inch in diameter. The flexion of the knee therefore amounted to a partial dislocation. The articular end of the tibia is correspondingly altered; it is markedly convex from side to side, and from before backwards the articular facets are one-half of the normal size—the external occupying the outer and posterior angle of the articulating area, the internal retaining its normal position.

Only the upper half of the articular surface of the *patella* was in contact with the femur; there is no recognisable division of its surface into external and internal facets.

At the *ankle,* where the foot is *flexed* and to a slight degree everted, the anterior fourth of the inferior articular surface of the tibia has been absorbed, and the superior surface of the neck of the astragalus is in contact with a rough area on the anterior suface of the lower end of the shaft of the tibia. This area was covered with condensed fibrous tissue.

*The left lower extremity* possessed a limited range of movement; it is adducted and rotated in; there is a *partial dorsal dislocation at the hip*, with marked deformity in the head of the femur. The inner or lower third of its convexity articulated with the posterior and prominent edge of the acetabulum, and presents a series of irregular projections alternating with deep excavations, at the bottom of which the wasted spongiosa of the interior is exposed: in the recent state this surface was invested with fibro-cartilage. The upper part of the head is occupied by a deep groove which faces outwards, and which probably lodged a specially contracted portion of the fascia lata. The unoccupied cavity of the acetabulum is very uneven, and was devoid of articular cartilage.

*At the knee-joint* there is a moderate degree of flexion along with internal rotation of the leg. *The foot* is in the position of complete extension.

*Indications of pressure-sores.*—As a result of the distortion of the limbs, the right leg was pressed against the left thigh, and at the points of contact there were deep sores on the soft parts; there are also evidences of this pressure in the bones concerned. The shaft of the tibia at the junction of its middle and lower thirds is curved towards the fibula, and the area pressed upon is depressed, rough, porous, and pigmented. On the surface of the shaft of the femur, a little below its centre, there is a similar rough pigmented area.

## Commentary on the Case.

In reviewing the salient features of this case, we may endeavour to associate the phenomena observed during life with the lesions discovered after death, and arrive, if possible, at some conclusion as to their period of occurrence and method of origin. There is, in the first place, the birth of an apparently healthy child. It is the subject of microcephaly, but this is not recognised. Before the first dentition is over, there gradually develops a hemiplegia of the right side, which prohibits the erect posture. The hemiplegia is apparently complete before the occurrence of "fits"; the latter commence in the third year, and frequently recur until the age of 26; they are described as

being characterised rather by coma than by convulsions. There is no evolution of the cerebral functions; the child becomes and remains an idiot, not even possessed of the faculty of speech. An examination of the brain reveals a moderate degree of micrencephaly and a gross lesion in the left cerebral hemisphere, the brain tissue of the Rolandic area being represented by a thin membrane roofing in the lateral ventricle. Taking facts and history together, we may assume that at some time during the second year of life there occurred in the imperfectly developed and therefore susceptible brain a vascular lesion (thrombosis or hæmorrhage) in the distribution of the left middle cerebral artery; that this lesion was of gradual development, and so damaged the whole of the brain tissue in the area concerned that it is finally replaced by a membranous layer of connective tissue. This cerebral lesion of the motor area being irreparable, changes inevitably follow in the corresponding pyramidal tract and in the paralysed side of the body; this secondary degeneration does not remain limited to the tract originally affected, but spreads to the grey matter, and to the white columns of the cord as a whole. The paralysed extremities of the right side do not grow *pari passu* with the rest of the body and become the seat of contracture,—in the arm the flexors and pronators overcoming the extensors and supinators, in the leg the flexors and inverters overcoming the extensors and everters. There is no facial paralysis or asymmetry (it is quite possible, however, that this existed in the first instance). That the muscles of the trunk participated in the hemiplegia may be inferred from the contracture scoliosis of the spine, which is essentially lumbar, with its concavity to the paralysed side.

The *left* lower extremity, which was not originally paralysed, became subsequently almost, if not entirely useless, and was also the seat of contracture when the patient came under observation. The probable explanation of this is to be found in the extension of the sclerosis within the spinal cord, from the pyramidal tract originally involved, to the other strands and to the grey matter. This view is quite in harmony with the changes in the cord which have been observed in this case, and it certainly goes far to confirm the view that contracture of the limbs in cerebral palsies is the direct result of the secondary

changes in the spinal cord, and that cerebral contracture is, after all, a spinal symptom.

The only other explanation of the paralytic contracture of the *left* lower extremity in this case is, that at the outset the hemiplegia was bilateral (diplegia), and that the left arm was either little involved or that it subsequently recovered. Against this view we have, however, the following facts—viz., the absence of a cortical lesion in the right hemisphere, and the history that the paralysis and contracture of the left lower extremity developed at a later period than those on the right side.

The comparatively slight difference in the length of the long bones on the two sides is in accordance with the view that the degeneration in the cord was at first limited and afterwards became more general, so that the bones of the left arm and leg, and especially the latter, shared in the arrest of development. It is to be remembered, however, as pointed out by Sir George Humphry, that deficiency in length is a less marked and constant feature of the bones in paralysed limbs than deficiency in lateral growth.

It is to be noted that there was no difference either in length or in girth between the long bones of the hands and feet on the two sides. As one would anticipate, there was no difference in the dimensions of the bones of the shoulder and pelvic girdle, or in those of the trunk.

In conclusion, it may be granted that such a degree of arrest of development, of wasting, and of distortion of the skeleton as is presented by this specimen is only sufficiently accounted for when we consider the three concurrent conditions under which it originated—viz., (1) micrencephaly, (2) destruction of the motor centre and conducting path, and (3) lifelong recumbency and disuse.

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## References to Literature.

These have been omitted in the text of the paper, and are too numerous to be given in full. The writer is especially indebted to the elaborate monographs of Giacomini and of Marchand on Microcephaly, and to the writings of Déjérine, Gowers, William Osler, Sigm. Freud and Oscar Rie, B. Sachs, and of Peterson and Fisher on the Cerebral Palsies of Children.

## CALCAREOUS BODY REMOVED FROM THE BURSA OVER THE PATELLA. By Prof. A. M. BUCHANAN, M.D., Anderson's College Medical School, Glasgow.

THE subject of this note was a male, æt. 71 years, who died from senile decay. It was impossible to obtain any information in regard to the history of the case or the occupation of the individual.

On examining the anterior aspect of the right knee-joint a firm swelling was felt, of the consistence of bone, and resembling

in its outline the patella, over which it was situated, and upon which it was only partially movable.

An incision having been made over the swelling it was seen that the body was contained in the bursa over the patella, from which it was easily removed with the finger.

On examination it presented an irregularly cordate appear-

ance. It was broad above, and tapered off below to a rounded apex. The upper border presented a notch at the centre, differing in this respect from the upper border of the patella. The lateral borders projected above, the left more so than the right, and they sloped downwards towards the mesial line, the left border more so than the right.

The whole body had a very irregular, mulberry-like appearance, particularly on its anterior surface which was convex in outline, the posterior surface being slightly concave. It weighed half an ounce, and its measurements were as follows:—

| | |
|---|---|
| Transverse (at upper border) . . | 4 cm. |
| Do. (at commencement of lateral slopes) . . . | 3· " |
| Do. (at apex) . . . . | $1\frac{1}{2}$ " |
| Vertical mesial (opposite notch) . . | 3 " |
| Right oblique . . . . . . | 4 " |
| Left oblique . . . . . . | 4 " |
| Breadth of notch . . . . | 1 " |
| Depth of do. . . . . | $\frac{1}{2}$ " |
| Antero-posterior (above) . . . | $1\frac{1}{2}$ " |
| Do. do. (below) . . . | 1 " |

On minute examination it was found to be composed in great part of calcareous matter, arranged in irregularly rounded masses, which were imbedded in a dense, pinkish tissue, and were prominent at parts, giving the subject a warty appearance.

The tissue presented the characters of white fibrous tissue mainly, with what appeared to be an admixture of unstriped muscular tissue. The muscular element, however, is doubtful, as the portion removed for microscopical examination had been decalcified, and nuclear staining was interfered with.

All the joints and other bursæ were normal.

# PUCE IRON-PIGMENTED RENAL CALCULI.

By Gordon Sharp, M.B. Edin.

Some two years ago I attended a woman of forty-five in two attacks of renal colic, and on both occasions she passed in the urine, some short time after the attack, about a dozen calculi. In size they vary from those weighing something like two grains to six grains. They are mostly smooth, beautifully polished, and intensely hard. Others are tuberculated, darker in colour, and not so much polished. Thus they mostly belong to the class of hemp-seed calculi. However, their most peculiar feature is their colour, which is a beautiful puce. When an attempt is made to cut them with the knife they are found to be extremely hard, and to scale rather than to cut. Layer after layer can be peeled off like the coats of an onion, and on sawing one straight through the middle this condition of layers is well seen. The centre is hollow, or nearly so, and the layers lose their puce colour as the centre is reached, and take on a brown coloration, although, all through, the colour is dependent on the same substance, namely, iron.

The colour is not common, and in making an examination one hardly could believe it to be due to iron, although such is the case. The iron is evidently present in the same condition as is found in the large quantities of iron found in the urine in cases of pernicious anæmia, that is, it does not give the reaction with ammonium sulphide, and is only detected after a small quantity has been fused on a porcelain slab or on a piece of platinum foil, along with a drop of strong nitric acid, to which, afterwards, a drop of dilute hydrochloric acid and a drop of solution of ferro-cyanide of potassium are added, when the characteristic blue colour is obtained. On account of the uncommon colour some of the powdered calculus was put through the various tests for pigments likely to be present, but in every case with a negative result. On fusing, no red or coloured fumes were observed (absence of anything of the nature of indican). Some of the powder was also dissolved in

34 per cent. hydrochloric acid, and a few drops of strong nitric acid added (M'Munn's indican test) without effect. The biuret reaction is not obtained (absence of uric acid). Millon's reagent has no effect, showing that no proteid (such as tyrosine) is present. Likewise no reaction is obtained with nitric acid, and subsequently the application of caustic potash, pointing to absence of xanthine.

When a portion of the powder is placed under the microscope, crystals of calcium oxalate are seen occupying the whole field, and of this substance the greater portion of the calculus is made up. The presence of this substance is further proved by fusing a small piece on platinum foil and dissolving in acetic acid, when it effervesces and gives a precipitate of calcium oxalate on the addition of ammonium oxalate in solution. The powdered calculus is, moreover, insoluble in strong acetic acid, but is readily so in hydrochloric acid.

The calculus is also soluble in strong sulphuric acid, and forms a red-violet solution. Strong nitric acid forms a reddish-yellow solution, slowly passing to yellow. These also point to iron. It is known that various salts of lead have an affinity for some of the pigments found in the urine, and on this account some of the hydrochloric acid solution was treated with a solution of sub-acetate of lead. A copious precipitate necessarily resulted, but it was quite white in colour, proving the absence of urinary pigment.

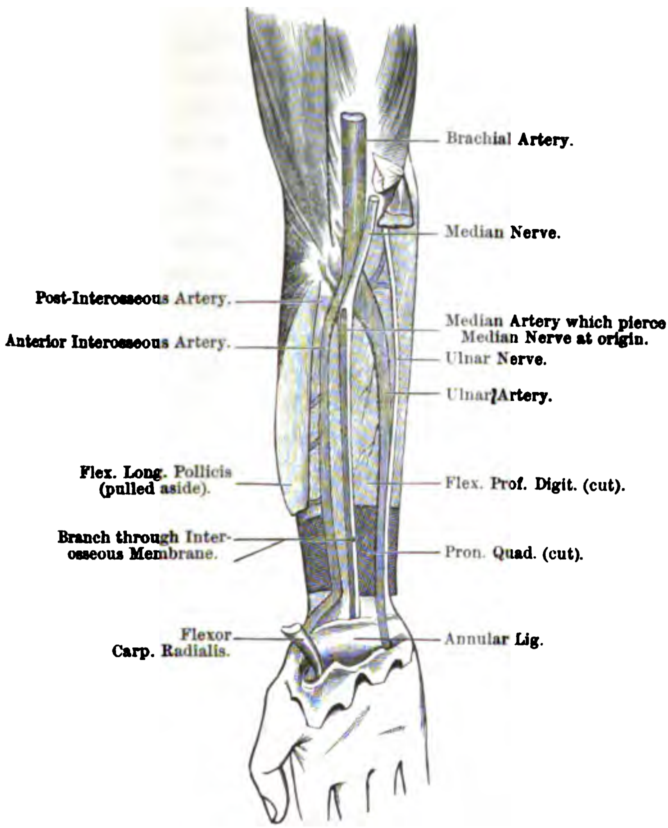
In looking over various collections I have been unable to find anything of the same colour, or even approaching the puce tint.

Although kept for over two years, and frequently exposed to the air and light, they have undergone no change in colour.

# A CASE OF ABSENCE OF THE RADIAL ARTERY.

By J. J. Charles, M.D., F.R.S.E., *Professor of Anatomy and Physiology, Queen's College, Cork.*

In the right upper extremity of an aged male subject, which was dissected last session in the Anatomical Rooms of Queen's College, Cork, the radial artery was found to be absent, and its place occupied by the anterior interosseous artery. The accompanying figure represents the arrangement of vessels in




the forearm. The upper extremity is now preserved in the Anatomical Museum of the Cork College. In the left upper extremity of the same subject, the radial artery was normal in

its course. As this case is one of extremely rare occurrence, I consider it advisable to append the following notes.

The brachial artery, after furnishing the radial recurrent branch which passes outwards beneath the biceps to the supinator longus, divides opposite the neck of the radius into the ulnar and interosseous arteries. The ulnar artery takes the normal course, and requires no special remark. The interosseous artery, a large and very short trunk, gives off a long and slender branch, the median artery, which pierces and afterwards accompanies the median nerve under the annular ligament to the hand; it then divides into the anterior and posterior interosseous arteries. The posterior interosseous artery passes above the upper border of the interosseous membrane to the back of the forearm, where it is distributed in the usual manner. The anterior interosseous artery—almost as large as the ulnar—lies on the interosseous membrane, having its normal relations till it gets under cover of the pronator quadratus, when it sends one branch through the interosseous membrane to the back of the wrist, and another inwards and downwards along the front of the ulna. The anterior interosseous artery continues directly downwards nearly to the lower end of the radius, beneath the pronator quadratus (in the position of the anterior communicating branch), when it turns abruptly outwards and then obliquely downwards under the tendons of the flexors of the fingers and thumb and of the radial flexor of the wrist, and gives off the superficial volar branch which runs downwards in the muscles of the thumb. It now pursues the normal course of the radial artery round the outer border of the carpus, below the styloid process of the radius and under the extensor tendons of the thumb, over the scaphoid and trapezium, to the space between the first and second metacarpal bones, where it enters the palm. Some of its branches are irregular; but there is no need for special comment either as to these branches or to the further course of the artery in the palm of the hand.

Quain, in his "*Commentaries on the Arteries*" (page 321), says that he never saw an instance of absence of the radial artery; but he refers to Prof. Otto's account of an old woman in whom the radial artery was absent in both arms, and the (anterior) interosseous artery enlarged to take its place.

## NOTICE OF AN INSTANCE OF MATERNAL IMPRESSIONS. A LETTER ADDRESSED TO PROF. M'KENDRICK.

SIR,—I send the following statement of facts which occurred in my own family circle, as they are, I think, of some scientific interest in regard to the possibility of prenatal influences affecting the offspring.

J. X., the child in question, was born on February 14, 1863, and she is still living.

In the previous June, Mrs X., her mother (then pregnant), was summoned to pay what was believed to be a farewell visit to her mother, Mrs Z., who was supposed to be dying. She paid a second similar visit about the end of July, and was deeply affected by the circumstances. Mrs Z., however, did not at that time die, but recovered, and died three years later, in 1865.

About the time of the first visit, which took place on June 27, Mrs X.'s husband gave her a flat band-bracelet, which at the clasp was just over half an inch in diameter. He clasped it himself on the right arm. He caught the skin in putting it on, hurting her considerably, and she with difficulty repressed a scream. The pinch caused a red mark on the arm.

When J. X. was born in the following February she presented a ridiculous likeness to an old woman, and was nicknamed

"grannie" and "nutcracker" from the first. None of Mrs X.'s other children were the least like her, and I can myself remember hearing of her likeness to her grandmother (Mrs Z.), and of her queer appearance.

Besides this, she had a red mark on the right forearm, just

above the wrist on the outside, and not far from the spot where the clasp of the bracelet would naturally come if put on with the clasp outside.

The present shape of the marks is given in the inclosed woodcut, which also gives a reduced drawing (scale ⅓), which will show pretty much the appearance they must have had when J. X. was born. The lowest mark in the drawing, which is the one highest up the arm, is fainter than the other three, and until I asked for an exact tracing of the marks Mrs X. was unaware of its existence.

Mrs X. believed that the marks originally bore a strong resemblance to the red marks caused by the pinch; and it would appear that at the time of J. X.'s birth this may well have been the case, but her memory of the original mark is evidently inexact, and not reliable as to details.

When J. X. was seven years old she developed epilepsy (originally in teething convulsions), and is now, I regret to say, a great sufferer from the complaint.

Mrs X. is still living, aged 62. A. L., who was the upper-nurse at the time, perfectly remembers all the circumstances, both the original injury to the wrist, the mark thereby caused, and the birth-mark on the infant, as well as the curious chiselled features, prominent chin, and old-woman look which distinguished J. X. as a baby.

Cases of this kind are so rare, that if the interest of the case depended on the birth-mark alone, the exact resemblance of the two marks would be of great importance, in order to exclude accidental coincidence, and satisfactory evidence of such exact resemblance must always be, as in this case, very difficult to obtain. I believe, however, that it is admitted by many that great agitation of the mother during pregnancy may tend to develop diseases such as epilepsy in the offspring; and if so, I think the triple coincidence of the wrist-mark, the strange likeness to an old woman, and the subsequent epilepsy, when taken in conjunction with the details given in this letter, may make the case worthy of being recorded in your Journal.—I am, &c.,

J. T.

To Professor M'Kendrick, M.D.

# ABNORMAL MUSCULAR CONTRACTIONS AND THEIR EFFECTS.[1] By Sir M. George Humphry, M.D. Cantab., LL.D., Sc.D., F.R.S., *Professor of Surgery in the University of Cambridge, and Surgeon to Addenbrooke's Hospital.*

From the *Lancet*, May 19, 1894.

I propose to say a few words respecting certain morbid phenomena which we observe in connexion with variations in the contractions of muscles.

## Preternatural Muscular Irritability.

First, on those depending upon excessive muscular irritability. In considering the irritability of muscular fibre we must remember that there are two factors concerned—the irritability of the muscular fibre itself and the irritability of the nerve or nerves supplying it. Seeing, however, the difficulty which physiologists have found, even with the parts exposed under their eyes, in discriminating between these, it is scarcely to be expected that we should be able to make a distinction between them, practically, in the living body. Indeed, they are so intimately associated that it is most probable they usually participate in their variations—that in those persons in whom the nervous system is over-susceptible the muscular system is so likewise, and *vice versâ.* With regard to both, or rather the combination of both, we find considerable variations within what we may call the normal area. The two are much more alive in some persons than in others. Some persons start at the bang of a door, which has no effect upon others; and in some the will impulses are more briskly responded to than in others, the movements being quick, perhaps jerky. On the whole, within the normal area some relation—one of inverse proportion—is observable between force and irritability, the muscles of women and delicate persons being more readily called into action than those of men and of strong persons. The greater rapidity of action in the former in some measure compensates, may even more than compensate, for the greater power in the latter. This, it may be observed, is in accordance with a general principle of construction in the human frame in which, by the attachment of muscles in the proximity of joints, power is, with great advantage, sacrificed to rapidity of action. In the knee-jerk, or patellar reflex, we have a good illustration of the differences of muscular or neuro-muscular susceptibility in different persons. In some, those chiefly of the delicate and sensitive type, a gentle tap upon the tendo patellæ will cause a marked forward jerk of the leg, whereas in others it will produce little effect; and this variation, which within certain limits may be no indication of disease, must be borne in mind in observations with reference to the patho-

[1] A paper read before the Cambridge Medical Society.

logical import of this and other similar phenomena in the clinical examination of patients.

These and many others that might be adduced—and many will occur to you—are instances of variations of muscular irritability within what I have called the normal area—that is, variations which are associated with certain temperaments or constitutions, and which are habitual or natural to them. There are, as may be expected, many conditions, chiefly those of lowered bodily tone, in which irritability exceeds the normal bounds—the bounds, that is to say, normal to the particular individual—and becomes a malady; such, for instance, as the chorea of delicate children, in whom the system has by some cause become morbidly atonic and in whom the slightest excitement—the being addressed, even in a familiar manner, or an ordinary volitional effort—will induce numberless involuntary movements. In the same category, associated with incompleteness of directing force, may be ranged the unsteadiness of the movements of the hand and other parts—the paralysis agitans—in the aged and also in the drinker; and in both of them there is usually more or less nervous as well as muscular atony, with perhaps atrophy, exhibited, or rather observable, the atrophy being more particularly evinced in the shrinking of the brain. The startings of the limbs in going to sleep in those who are somewhat exhausted by fatigue or anxiety, or who are in lowered health, are of like nature. The same thing is evinced occasionally in particular muscles, especially by the twitchings of the delicate fibres of the orbicularis oculi lying upon the upper eyelid, which are habitually and normally called into action by the inappreciably slight stimulus of moisture upon the cornea. Such movements are also liable to occur in muscles which have been enfeebled by suspension of the influence of the will. We have all heard of the spasmodic jerkings in Nelson's stump, noticeable when the enemy's ships were in sight and when action seemed imminent. Not long ago a young woman in the hospital was so tormented by jerkings forward of the stump of her thigh that I found it necessary to remove a piece of the anterior crural nerve to give relief, and I performed the same operation in a girl in whom the twitchings of the quadriceps extensor cruris prevented the healing of the fore part of the wound after excision of the knee. Frequent examples of the same kind are furnished by the painful startings of the parts experienced by those who are suffering from ulceration of articular cartilages, and which is so characteristic of that condition. These startings are most noticeable when the knee is the seat of disease. Observe the circumstances under which they occur. The patient is probably enfeebled by the disease which has been going on in the knee. The muscles which act upon the knee have been still further enervated and rendered flaccid and preternaturally irritable by suspension of their action. The patient is in the relaxed, unstrung state of commencing sleep, and is suddenly woke up by the severely painful starting movements in the diseased knee, and this probably recurs when he again falls asleep. The slightest thing in severe cases will produce this effect—some little disturbance in the room or movement of the bed, some slight move-

ments of the rest of the body, such as are often experienced by the weak, or even by the strong, on going to sleep, and which are especially liable to occur in the hyper-irritable muscles of the affected limb; or some little change of position or other change in the knee excites reflex action of these muscles. Any of these causes are sufficient to induce the painful result, and it may be brought about in the waking hours in like manner. It may commonly be controlled or prevented and rest given by fixing the limb upon a splint, in the extended position if possible, with a bandage carefully applied along its whole length.

We all know how much nervous and muscular action is facilitated by habit, the paths of the transmission of impressions being rendered smooth and easy by the traffic along them, or, rather, the chemical and other changes associated with the exercise of the requisite function being facilitated by the frequent occurrence of them. This may go to such an extent that movements often indulged in or excited by some irritation will persist, as it were, spontaneously—a phenomenon which is especially noticeable in the muscles of the face and neck, causing repeatedly recurring spasmodic closure of the eyes, pouting of the lips, twitching of the corners of the mouth, or noddings of the head. Moreover, the contractions of certain muscles, thus commenced and not duly counterbalanced, may become permanent—to wit, that of the rectus internus oculi in children who become squinters from thoughtlessly having contrived to imitate a squint in others. Hence the other eye has to be closed for a time to restore the proper extensibility of the over-excited muscle as well as that harmonious give-and-take, or balance, between opponent muscles which is requisite for the movements of the eye and for so many of the other movements of the body. Wryneck may be induced in a similar manner, and is curable in the early stages—as we found the other day in a young woman in the hospital—by resting the head upon a pillow. In writer's cramp the neuro-muscular apparatus, over-fatigued and exhausted beyond the power of repair by persistent efforts, in many cases passes beyond the stage of spasm, or cramp, into that of more complete paralysis. Not long ago among the out-patients was a strong and otherwise healthy man, engaged in a printing office, who had lost the power of extending the fingers of one hand because the flexor muscles, habituated to manipulate a roller, had become contracted, firm, and knotty. We fixed the fingers and wrist in an extended position upon a splint, but I do not know the result, for we lost sight of him. In these and similar cases, such as the cramp of piano players and violinists, the wearied and enfeebled muscles first undergo an increase of irritability and a tendency to spasm, which may be followed by more or less imperfect subjection to volitional impulses or paralysis. In the early stages they are commonly relieved or cured by the repose requisite for structural repair; but we find that repose must in many cases be long continued, forasmuch as a muscular or nervous structure repeatedly and much fatigued undergoes change which, in greater or less degree, unfits it for the gentle, delicate processes of reparative nutrition. I do not attempt to

reconcile the abnormal irritability and spasmodic contractions of muscles in these enfeebled or exhausted conditions with experiments made in the physiological laboratory, for these seem to point rather in the opposite direction, and indicate that a diminution of irritability is the usual concomitant of the lowered nutritive conditions attendant on fatigue, defective supply of arterial blood, or other causes.

It is interesting to note that, although the various involuntary muscular contractions to which I have alluded are most common in enfeebled persons and enfeebled muscles, they do not, even when long continued and, it may be, violent, produce further exhaustion or sense of fatigue. This is in accordance with the recognised, though not easily to be explained, fact that involuntary movements are commonly not attended with the same indications of wear or fatigue as are those which are the result of voluntary effort. Possibly, as has been suggested, it is the effort of the will wherein lies the exhausting part of the process of ordinary voluntary muscular exertion.

## Fractures caused by Spasmodic Muscular Action.

While upon the subject of muscular spasm I may remark that the volitional impulses cannot call forth the whole amount of force which a muscle—probably any muscle—is capable of exerting, possibly because they cannot call more than a certain quantity of the muscular fibres into action at one and the same time; and the strength of the skeleton in each person is adapted to bear the strain of the greatest voluntary contraction of the muscles which can at any one time be brought to bear upon it in that person. It would be an ill construction if it were much stronger than this; and it follows that a bone is very rarely broken by any voluntary muscular action—by any effort, that is, of the will. The bone—perhaps the only bone—which occasionally suffers in this way is the humerus, at or near its middle joint, above which part are inserted the powerful muscles—deltoid, pectoralis, latissimus dorsi, teres major, and coraco-brachialis—which wield the upper limb upon the shoulder, and which have so long a leverage of the upper limb against them. Thus I remember an undergraduate in whom this bone gave way when he was "putting the weight," and an old man who broke it in pulling himself upstairs by the handrail. I do not suppose that any purely *voluntary* muscular effort would break the patella, or ever has done so; but the sudden *spasmodic* contraction of the quadriceps extensor cruris caused by a slip in the semi-extended position of the knee does not infrequently break off transversely the upper larger half of the bone. The sternum has been snapped by the recti abdominis muscles under similar circumstances, and a former colleague narrated to me a case in which the shaft of the thigh bone was broken during the violent spasms that ushered in a severe attack of Asiatic cholera. In such cases it would seem that inordinately strong sudden impulses call into play simultaneously a larger amount and greater force of muscular action than the will can command, a force greater than the bony framework, calculated to meet only ordinary requirements, is

able to withstand.[1] These remarks apply also to the snapping of tendons and the rupture of muscular fibres. This last event is said occasionally to occur in the sterno-mastoid in parturition and to be one cause of wryneck. It now and then happens in the rectus abdominis, the strain upon which in raising or flexing the trunk upon the pelvis is very considerable, and it may be that the segmentation of this muscle by tendinous intersections tends to prevent such rupture by distributing among the fibres and bundles of one part the pull caused by the contraction of particular fibres or bundles of another part, and that the like purpose is served by the homologous segmentations of the long, very powerful, and suddenly acting lateral muscles of fishes. The rectus abdominis is the longest muscle in the body next to the sartorius, and has much greater demands upon it than that muscle for sudden violent action, and it therefore stands especially in need of some such arrangement to prevent the disaster which still does occasionally take place.

### PERSISTENT CONTRACTION AND SHORTENING.

Let us pass now from the consideration of these states of morbid irritability and spasmodic muscular action to the consideration of conditions of a somewhat opposite nature in which the muscles have a tendency to shorten in a more or less persistent or permanent manner. I have already mentioned this to be an occurrence occasionally ensuing as a consequence upon exalted or maintained irritability and correspondent muscular action, which I exemplified by some cases of wryneck and strabismus, and many other instances of the like kind might be adduced.

The shortening to which I refer seems to resemble not so much a muscular action as the slow process of contraction which takes place in blood plasma and in organised plastic or lymph formations produced by inflammatory process, and in cicatrices, and to some slight extent that which occurs in rigor mortis. It is not, however, so rapid as the latter or so evanescent; it is not attended with the same loss of irritability: and is, indeed, not so obviously a death change. Whether it is attended with the changes in form of the sarcous elements and the chemical changes which occur in rigor mortis or in ordinary muscular action I do not know, and I am not aware that any experimental observations have been made in reference to it. It may perhaps be best regarded as the result of a sort of shrinkage-property appertaining to the vascular, connective, and other tissues, as well as to muscular fibre, in varying degree, which adapts them to the varying and ever-recurring changes of volume and circumstance in the living body, so maintaining a certain consistency in the soft parts of the body and preventing flaccidity. At the same time there is

[1] In a case recorded (*Brit. Med. Jour.*, March 31st, 1894) as "compound fracture of the tibia and fibula by muscular action" the result seems to have been caused by a sudden violent twist of the limb under the weight of the body, the foot being fixed on the ground, and is scarcely, therefore, an example of fracture by muscular force.

need of the several circulatory and other changes attendant upon living processes to keep it in check and to restore the tissues from the condition into which they have shrunk or contracted, just as in a more marked manner a stricture requires occasional stretching with a bougie to maintain the patency of the narrowed canal. When muscles are disused this condition of shrinking or contraction commonly sets in, and in the limbs the greater or stronger mass of muscles at each joint, which are usually on the flexor aspect, dominating over the extensors, draw the several parts into the flexed position and hold them there. Hence it is that the action of the extensors, under the influence of the will in the ordinary movements of life, is necessary in order that the flexors may be often stretched and so prevented from assuming the shortened and less pliable or less yielding state which is apt to be consequent on long-continued repose. The frequent and sometimes startling movements of the fœtus in utero doubtless serve, among other purposes, to give and maintain this muscular balance, and their failure is the probable cause of certain congenital deformities which we often see, such as talipes varus. Bedridden persons, lying with the lower limbs habitually bent and unused, gradually lose the power of extending the hips, knees, and ankles, while the extensor movements of the upper limbs, maintained by various voluntary actions, prevent the like rigidity of the flexors in them. It is, therefore, very important, especially when there is a prospect of recovery from the bedridden state, to prevent this shortening of the flexors, and consequent fixity of the limbs, by maintaining frequent voluntary or passive extensor movements. This is the more important because the ligaments, in process of time, shorten like the muscles, and offer, perhaps, even more resistance than the latter to the restoration of the movements of the limbs.

## Contractions of Joints.

Attention should also be paid to this in the treatment of diseases of joints, for one of the difficulties we often have to deal with after the disease has passed away is the contracted or shortened condition of the dominant muscles, and the inability of their opponents to effect the requisite stretching of them. Another difficulty associated with this rigidity is the pain in the contracted muscles. It commonly, for some reason, is referred to their tendons, and is in many cases severe, perhaps unbearable without an anæsthetic, when any forcible attempt is made to stretch them.

One of the parts in which this result is most common, and to the prevention of which the attention of the surgeon has been too little directed, is the shoulder. The extension or abduction of that joint—the raising, that is, of the upper limb from the side—is, even in the healthy state, rather a fatiguing movement. The carrying it to its full extent is almost peculiar to man, and the maintaining the limb at a right angle with the trunk will soon weary the strongest person. The fact is that the adductors—the pectoralis, latissimus dorsi, and teres major—are stronger, have far better leverage, and are more

favoured by gravity than their opponent abductors—the deltoid and the short muscles about the joint—and stronger efforts are required of them. Hence, if the joint be kept at rest, with the arm to the side, on account of disease or injury which may be slight, or in consequence of some injury to the clavicle or any part of the upper limb, such even as fracture of the radius near the wrist, the deltoid soon loses the power of stretching its opponents, gives in and speedily wastes, and the patient is unable to raise the elbow. After a time the difficulty is further increased by the shortening or shrinking of the under part of the capsule of the shoulder-joint, with perhaps adhesions of the wrinkles or folds into which this part of the capsule is thrown in the adducted position. Pain is caused by any attempt at movement, and in some cases is felt at other times, especially at night. The patient readily yields to the popular persuasion that a "bone is out," and probably resorts to a quack to "put it in." The frequency with which we meet with the condition referred to is sufficient evidence that medical men are not properly alive to the liability of the occurrence and to the necessity of taking the measures requisite to prevent it. These measures are very simple. In all injuries at or about the shoulder, including dislocations of the shoulder and fractures of the clavicle, care should be taken as soon as it can be done with safety to move the elbow from the side and raise the arm to a right angle with the trunk. This should be done on each occasion of removing the bandages, and with more frequency and persistence as the time after the accident increases. The same should be done in all other cases in which it is desirable, for purposes of treatment of any affection, to keep the arm to the side, and it is most important to attend to this when the patient has passed or reached the middle period of life. Much benefit to the patient and saving of reputation to the surgeon will be gained by judicious attention to this point.

When these precautions have not been taken, two or three months after the accident, supposing there to have been one, the shoulder will have become fixed and perhaps painful, the pain extending down the arm, and the parts about the shoulder, especially the deltoid muscle, will be wasted. The patient, unable to raise his arm or put his hand behind him, and impeded in various ways, becomes dissatisfied, has wisely lost faith in embrocations, rubbings, and the effect of time, and clamours for relief. This may be given in one of two ways. The first is by fixing the shoulder and carrying the arm suddenly and forcibly from the side to a right angle with the trunk, which is the normal limit of shoulder-joint movement. In this process, which is the quack or bone-setter's plan, the adhesions which have formed at the under part of the joint are torn, and the capsule also, at this part, may be more or less torn, this being attended sometimes by a snap or sound simulating a "bone going in," and contributing much to the credit of the quack; the abductor muscles are stretched, and much is gained towards the restoration of the movements of the shoulder. This heroic method, however, is severe, and is not altogether unattended with risk, though I have not known any particular evil to result from it in my own practice, and it is not always effectual. I

commonly resort to a slower and gentler plan of stretching by directing the patient to sit habitually with the elbow raised on a table or some higher level, to sleep with a stout bolster fixed between the arm and the side, and to exercise the limb many—a hundred or more—times a day by raising the hand, creeping up, as it were, with the finger upon the edge of a door till the top is reached, holding on there for a time and then bringing the hand down slowly. In this way the adductor tissues are gradually stretched and the abductor muscles are strengthened; baths, shampooing, massage, &c., may aid, but liniments and embrocations are worse than useless, because they divert attention from that which is really needed and waste time. It is one of the many instances in which patient perseverance in treatment is necessary and will be rewarded.

These remarks are applicable, *mutatis mutandis*, to other joints, particularly those of the lower limb. In the knee, for instance, the power of full extension—such extension as gives a slightly curved outline to the part with the convexity backwards, and which brings the flat under surface of the condyles into contact with the tibia—is easily lost and with difficulty regained. It requires the full assent of the flexor muscles as well as of the posterior ligaments, which are then tightly stretched over the back part of the condyles of the femur, forasmuch as the tibia during this movement, and as a necessary part of it, slides a little forwards beneath the condyles. Now if the knee be allowed to remain bent, in consequence of accident or disease, the flexors, acquiring proportionate leverage, soon preponderate and shorten, the posterior ligaments contract, and much difficulty is experienced in extending the joint, and there is often very great difficulty in effecting complete extension. Indeed, as we know, the flexors not infrequently draw the tibia a little backwards upon the femur, causing that slight subluxation which adds a further serious obstacle to the sliding movement of the tibia requisite for extension. Many limbs are rendered permanently useless by this deformity, or resection of the joint is needed to enable the foot to be placed upon the ground. I do not mean that this ill result can always be avoided. Children with affection of the knee are often allowed to go limping about till the flexed position is assumed, the joint becomes habituated to it, and there is much difficulty in effecting extension. The liability to this occurrence should, therefore, be borne in mind in the early treatment of knee affections, even though they be slight, and measures should be adopted to meet it. It is important also to beware of the same tendency in the foot and ankle under various circumstances. The weight of the bedclothes, for instance, upon the toes in persons long recumbent may induce it; and it is no infrequent source of trouble in the after-treatment of fractures of the leg as well as of disease of the ankle.

### Hammer-toe.

The position assumed by the toes is an illustration of the same influence; they are laid up in leather and not used. The phalangeal joints are kept flexed by the dominance of the flexor muscles, and in

most persons can be only imperfectly straightened by the action of the extensors, while the metatarso-phalangeal joints are hyper-extended by the pressure of the toes upon the ground, and the extensors acquire more or less dominance over these joints. This, which becomes in each person what may be regarded as the normal state in the shoe-clad foot, is occasionally exaggerated, more particularly in the second toe. That toe is more than any other at a disadvantage by reason of the encroachment upon its territory by the great toe, which fashion pushes outwards. Hence it comes about that the first phalangeal joint of the second toe is often projected markedly upwards, constituting what is called "hammer-toe," and becomes the seat of a painful corn, the annoyance being such that amputation of the toe is not infrequently resorted to for relief. The condition is aggravated and confirmed by contraction of the lateral ligaments and other tissues on the under surface of the joint, and I have found ankylosis of the bones here; but that the condition is primarily due, as I have said, to contraction of the flexor muscles, and not, as has been urged, to contraction of the ligaments, is proved by the fact that in the early stages the toe readily assumes its natural position if the flexors are relaxed by pressing down the first phalanx. The great toe, which has a special extensor muscle, and is commonly pressed in its whole length upon the ground, is less liable to this affection. It may, however, be shoe-bullied into the troublesome state of "hammer-toe" in which the phalangeal joint is thrown upwards, and the extremity and nail of the toe are pressed upon the ground.

### The Elbow.

In the instance of the elbow the supinator longus stands out as a marked adjunct to the other flexors of the joints; and long-continued, patient extension by mechanical means is needed to overcome the combined contraction of these muscles.

### Deformities of the Hand.

In the hand the deformity—a not uncommon result of chronic rheumatism—usually manifests itself in a flexure of the fingers upon the metacarpus and a slanting of them towards the ulnar side, this last being due to the preponderating influence of the so-called "abductor" muscles. The first phalangeal joint of the little finger is often somewhat flexed, and this is the case usually with the terminal phalangeal joints of all the fingers; but the middle joints are not unfrequently over-extended so as to be rendered convex on the palmar aspect. It will be observed that these positions are to some extent the reverse of those which usually occur in the toes, where the metatarso-phalangeal joints are extended by the pressure upon the ground and all the phalangeal joints become flexed.

The position of the toes, as I have already said, is probably due to their being pushed upwards on the metatarsus by pressure upon the ground, which will have an influence in causing flexure of the

phalangeal joints, forasmuch as the flexor tendons are thereby put and kept upon the stretch; and it may be remarked that this condition—hyper-extension of the metatarso-phalangeal joints and flexion of the phalangeal joints—is most marked in cases of talipes equinus in which the bearing upon the balls of the toes is nearly vertical. But why in the disabled hand the proximal phalangeal joints should so often be hyper-extended, while the terminal joints and the metacarpo-phalangeal joints are flexed, is not easy to explain. It is, moreover, a combination of positions which few persons can voluntarily effect, flexures of both phalangeal joints being habitually coördinated, in consequence, I suppose, of the flexure of the terminal phalanges, to which the lateral parts of the extensor tendons are attached, causing tension of these lateral parts and, with that, a dragging forward and relaxation of the middle parts which are attached to the second phalanges. The same influence exerted along the extensor tendons will have its effect upon the metacarpo-phalangeal joints as well as upon the phalangeal joints, and thus facilitate the harmonious combination of flexor movements requisite for grasping with the fingers. This view of the manner in which the normal combination is facilitated does not, however, assist in explaining the abnormal combination of hyper-extension of the proximal phalangeal joints with flexion of the terminal joints to which I have referred, and which is a not uncommon condition in rheumatic and some other affections.

## In Paralysis.

In paralysis the same results of disease manifest themselves in the various parts of the affected limbs. The muscles waste, and the shortening process, which in time affects the connective tissue as well as the fibres of the muscles, has full scope in the flexors, now unresisted by voluntary or any other action of the extensors. Thus in the upper limb the arm hugs the side, the elbow and wrist become bent, the thumb is drawn in to the palm, the fingers are bent upon the metacarpus and slanted towards the ulnar side, the terminal phalangeal joints are bent, and the proximal joints are flexed in some instances and in others extended. In the lower limb the weight of the limb and of the bedclothes and other influences commonly suffice to maintain extension of the hip and knee, and the pressure of the sole upon the ground will often have the like effect upon the foot and ankle. In cases of infantile paralysis of the leg and foot, however, how common it is to find the heel raised, the arch of the foot heightened, and the phalanges much flexed, and how difficult it is to overcome the deformity—the talipes equinus and cavus—thus induced, even though the paralysis may have subsided.

## Congenital Club-foot.

The subject of club-foot carries us into fœtal life, during a large part of which the jerky movements, in whatever way induced, serve the purpose of maintaining muscular balance; and they are continued

after birth in the peculiar stretchings of the fingers, toes, and other parts noticeable in infants. These subside as voluntary influence comes to bear upon the muscular system. Congenital club-foot, which usually takes the form of talipes varus, is due, I apprehend, to a deficiency of these movements and a consequent want of resistance to the contraction of the dominant muscular masses, whereby the foot is inverted, the plantar arch is rendered excessive, and the heel is raised. The inversion and the plantar flexion in these cases are usually more pronounced than the heel elevation, which may be due to position in utero. At any rate, in infantile paralysis the inversion is usually less pronounced than the heel elevation and the plantar flexion. The slight obliquity in the neck of the astragalus, by some regarded as a cause of the deformity, is, I believe, in reality due to the traction exerted upon it as a consequence of the deformity. Specimens illustrating this view are mentioned by Dr Griffiths, with an account of a case of talipes dorsalis, in the *Brit. Med. Jour.* of December 20, 1893.

### Involuntary Muscles.

How far do the above remarks with reference to hyper-irritability on the one hand, and chronic contraction or shortening and shrinking on the other, apply to the involuntary or unstriped fibres? It may be noted that the capability of stretching and the range of action of these muscles exceed those of ordinary voluntary muscles. The healthy urinary bladder, for instance, contracts from the fully distended condition when it holds a pint or more till the last drops are expelled, and this it does quickly. The same is true, though less obviously, of the stomach and other parts of the alimentary canal. They all maintain a certain continuous pressure upon their contents by a process analogous to the tonic contraction of voluntary muscle, and may thus temporarily quite close up or obliterate their cavities, as we find to occur in the stomach after fasting, or when there is disease of the œsophagus. Whether this goes on to the persistent contracting and shortening, with shrinkage, of the muscular fibres and inter-muscular tissue is not easy to determine, though it seems probable that it may do so; and this condition of the bladder induced in old vesico-vaginal fistulæ seems to be one of the causes of difficulty in the treatment of these cases. Moreover, we know that increased irritability is easily induced by a slight disorder of the lining membrane or of the nerves supplying the mucous and muscular fibres. Thus we have irritable bladder, irritable rectum, and irritable stomach, the expulsion of the contents being frequent and the demand for it urgent, and a hyper-irritability of the sphincters may be an occasional cause of difficulty in the expulsion of the contents of the bladder and rectum. Hence there is, on the whole, reason to believe, what analogy would lead us to infer, that the involuntary muscles are subject to laws with regard to irritability and slow contractile process similar to those of the voluntary muscles. I say *similar*, forasmuch as the conditions under which the morbid

phenomena I am discussing occur are not quite the same in the two sets of muscles, possibly because the nerve relations of the two are, to some extent, different. Thus in chorea and other allied nervous affections which may be evinced throughout the voluntary muscles, the involuntary system—the urinary bladder, for instance—does not usually participate.

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## ANATOMICAL NOTES. By Edward Fawcett, M.B. Edin., *Professor of Anatomy, Univ. Coll., Bristol.*

### I. *The Left Phrenic Nerve with abnormal course relative to the Subclavian Vein.*

This rare abnormality occurred in a female subject. The phrenic nerve of the left side arose in the usual way, but passed downwards in front of the left subclavian vein, lying in a groove on that vein close to the junction of the vein with the left internal jugular.

I examined carefully the communicantes cervicis vel hypoglossi, but found them quite normal in origin, course, and in termination.

I may say that the course of the right phrenic nerve was quite normal.

### II. *An osteal outgrowth from the shaft of the Femur consequent on irritation by a needle.*

This curious outgrowth was found in the same subject as the above-described abnormality.

It was found during dissection of the quadriceps extensor muscle projecting inwards from the inner border of the shaft of the femur at about the junction of the upper $\frac{2}{3}$ with the lower $\frac{1}{3}$. It was about an inch and a quarter in length, and was something like a quarter of an inch in width at the base.

On examining it closely, it was found to contain a needle which showed considerable signs of absorption. The needle was very thin and black, and evidently belonged to the class of darning needles, though it was a small one.

I was unfortunate enough to lose sight of the specimen, as it was removed from the dissecting-room, during my absence, by the anatomical porter and buried. I had previously, however, obtained the needle.

From the size of the bony growth, and the amount of absorption of the needle, the latter must have found its way many years previously into the periosteum. I may say that the subject was over seventy years of age.

# INDEX.

PROCEEDINGS OF THE

# ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

## NOVEMBER 1893.

THE Annual General Meeting was held on Tuesday, November 28th, at St George's Hospital. Present—Professor D. J. CUNNINGHAM (President) in the chair, Sir Wm. Turner (late President), twenty members and visitors.

The minutes of the previous meeting were read and confirmed.

The Treasurer's Report for the year ending November 1893, showing a balance of £34, 4s. 11d. in favour of the Society, was adopted.

The TREASURER, in presenting his Annual Report, made the following remarks. The actual sum received in subscriptions for the past year was £21, against an expenditure of £66, of which £20 had been paid on account of the Index to the Journal of Anatomy and Physiology, now in the press. The balance of £45 thus resulting was met by the recovery of subscriptions in arrear to the amount of £35, thus leaving a final deficit of £10 to be met by the balance in hand. The list of members remained in a satisfactory condition as to numbers; and estimating the income and expenditure for the current year on the average of those of the past three sessions, as respectively £59 and £57, he concluded that the Society was in a position to meet all likely demands upon its resources, and to liberally illustrate its Proceedings and responsible publications.

Mr MAKINS, on behalf of Professor THOMSON, presented the *Report of the Collective Investigation Committee.* A vote of thanks to Professor Thomson was carried unanimously.

Dr H. W. M. TIMS was elected a member of the Society.

The following officers were elected for the following year:—*President*—D. J. Cunningham, F.R.S. *Vice-Presidents*—William Anderson; John Cleland, F.R.S.; Charles Barrett Lockwood. *Treasurer*—G. B. Howes. *Secretaries*—Ambrose Birmingham, M.D. (Ireland); A. M. Paterson (Scotland); Percy Flemming (England). *Council*—L. A. Dunn, M.B.; Wardrop Griffith, M.D.; G. H. Makins;

W. P. Herringham, M.D.; Alexander Hill, M.D.; Robert Howden, M.D.; R. Clement Lucas, M.S.; Alexander Macalister, F.R.S.; J. Yule Mackay, M.D.; T. H. Openshaw, M.B., M.S.; R. W. Reid, M.D.; Arthur Robinson, M.B.; H. D. Rolleston, M.D.; C. S. Sherrington, F.R.S.; T. W. Shore, M.D.; Johnson Symington, M.D.; Arthur Thomson; G. R. Turner; Sir W. Turner, F.R.S.; Bertram Windle.

Mr Stanley Boyd gave notice that he should at the next meeting propose two ladies as members of the Society.

Professor Cunningham made the following remarks on assuming the office of President:—

Gentlemen,—I am deeply sensible of the high honour you have done me in electing me your President for the year which we have just entered. It is no small distinction to have been called upon to succeed two Presidents of such outstanding eminence as Sir William Turner and Sir George Humphry. At the same time I am well aware that the compliment is one which is not so much paid to myself personally as to Irish Anatomists in general. The first president was very properly chosen from amongst English Anatomists; the second came from Scotland; and now the Society has decided to give Ireland her turn.

I can assure you that I have a due sense of the responsibility of the office. During the six years that the Anatomical Society has been in existence it has done a great work. The great personal influence of my two predecessors in this chair, backed by the energy and zeal of the three Secretaries who have been associated with them, have stimulated enthusiasm in anatomical pursuits in every direction—even the students who attend our schools have joined in the work. It is a difficult matter to estimate the good that has resulted: but for my own part I am inclined to think that the study of anatomy has been placed on a new footing in this country.

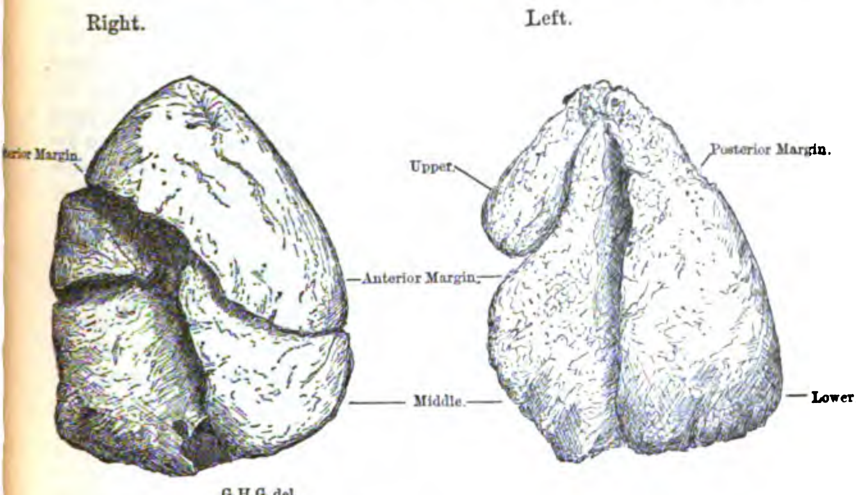
To some extent we may be considered to have entered this evening upon a new period in our career. I think we have every reason to look forward hopefully to the future. Let me assure you of one thing, that during my term of office no exertion on my part will be wanting to maintain the Society in its present state of high efficiency and usefulness.

The following gentlemen were nominated as members of the Society: —H. B. Grimsdale, B.A., M.B., proposed by G. R. Turner, W. P. Herringham, and H. D. Rolleston. R. C. Bailey, M.S., F.R.C.S., proposed by H. J. Waring, Walter Jessop, and G. H. Makins. G. B. M. White, F.R.C.S., proposed by G. D. Thane, G. H. Makins, and Percy Flemming.

Dr Bowles showed a specimen of a *Lung with four lobes.*

The lungs were removed from a patient who had died from phthisis.

The right lung has four lobes and the left three. These abnormalities seemed to me sufficiently remarkable to bring before the Society, especially as I have not been able to find any account of these unusual arrangements in the works which I have been able to consult. It will be seen from the accompanying drawing that, in the right lung, what should have been the posterior lobe is divided into two, its apex appearing as if cut of from the base, and the division going through almost to the root of the lung. In the left, it would seem that the lower lobe was divided into two portions, but the division does not penetrate so deeply into the substance of the lobe as the abnormal division on the right side. I thought, as the skeleton of the lung was practically formed by the bronchial tubes, that some explanation might be gained by their natural conformation. Professor Macalister points out that the bronchus of the right lung has




an eparterial branch and the left is wholly hyparterial, which he says "seems to indicate that the left lung has no lobe corresponding to the superior of the right."[1] Accordingly the left upper lobe corresponds to the right middle lobe (*vide* drawing), and the remaining two lobes in the left lung to the remaining two in the right lung; so it would appear that the lower lobe on each side has become divided into two. The drawings were most kindly made for me by Dr G. H. Goldsmith of St George's Hospital.

Dr Ewart regarded the additional lobe in the left lung as derived from the upper lobe, and as representing a middle lobe. From a study of the bronchial supply in Man, he was unable to agree with the view originally expressed by the late Professor Aeby, "that the left upper lobe was the equivalent of the right middle lobe, and that

[1] *Text-Book of Anatomy*, page 340.

the right upper lobe was without a representative in the left lung." The constituents of the middle lobe were to be found as complete in the left lung as in the right lung, although normally grouped into one lobe together with the constituents of the upper lobe. Abnormal cases such as the present one, in which the two sets of bronchi were kept apart by a supernumerary fissure, demonstrated at the surface of the left lung the structural equality, usually latent, of this lung with the right lung. In Man the bronchial tree showed almost absolute similarity in the two lungs, the upper-lobar bronchi and the middle-lobar bronchi in both of them agreeing in their number and in their mode of distribution. A slight difference was introduced on the left side by the asymmetrical position of the heart and of the aortic arch. The left main bronchus was lengthened and depressed. Moreover, its descending division (lower-lobar bronchus) was deflected backwards, and therefore unable to give origin, as in the right lung, to the middle-lobar bronchus. The difficulty arising from the deviations mentioned was met by the existence, in the left lung, of a short additional bronchial stem springing from the main bronchus immediately after its entrance into the lung, and termed by the speaker "bronchus impar" because it had no equivalent in the right lung. This intercalated internodium served as a common origin for the upper-lobar and for the middle-lobar bronchus. Thereby the point of origin of the upper-lobar bronchus was raised, and that of the middle-lobar bronchus was brought forward to the extent required.

The passage of the pulmonary artery above instead of beneath the left main bronchus was a structural necessity, not detracting in any way from the completeness of the left bronchial tree.

The fourth lobe in the right lung of the specimen exhibited seemed to consist of the bronchial district described by the speaker as that of the "posterior horizontal bronchus," a district so sharply defined as almost to invite its separation from the rest of the lower lobe by an additional fissure.

Mr Kempson showed, for Mr H. S. Pendlebury, *a specimen of an Accessory Supracondylar Ligament at the back of the Knee.*

The specimen exhibited, a right knee, which was dissected in the long vacation, shows a ligamentous band about 2½ centimetres long, whose fibres are connected distally with the origin of the external head of the gastrocnemius and the posterior part of the capsule. Proximally it is attached to the external supracondylar ridge of the femur, partly under cover of the origin of plantaris, but rising above the level of that origin; underneath this band run the superior external articular vessels. In the present Michaelmas term, another specimen of this ligamentous band has been found, stronger than the first described, but in this instance the main trunk of the superior external articular artery ran superficial to the ligament; only a small branch of the artery passed beneath it. This second occurrence of the structure led to an examination of a number of knee-joints, with the following results:—

| *Number examined* | *Ligament well developed in* | *Indications of it in* | *Absent in* |
|---|---|---|---|
| 11 | 5 | 3 | 3 |

Owing to the fact that in two cases the superior external articular vessels ran under cover of the band, one might perhaps have regarded it as present for the protection of these vessels. But in three subjects the main trunk of the superior external articular artery lay superficial to the structure, so that this explanation of its presence seems scarcely satisfactory. When, however, its attachments are taken into account, and also its strength (particularly in four of the knee-joints examined), it seems reasonable to suppose that it is an accessory band intended to strengthen that spot of the capsule into which the fibres of external head of gastrocnemius and ligamentum posticum Winslowii go, as it is so directed as to be made tense by contraction of the gastrocnemius.

In conclusion, it is worthy of note that in 25 femora examined, a small tubercle on the external supracondylar ridge was found in 3 specimens.

Mr Grimsdale showed *a specimen of Left Inferior Vena Cava without transposition of Viscera.* The specimen was found at a post-mortem examination of a patient who died in St George's Hospital.

Lying on the left of the aorta is the vena cava: it commences about ¾ of an inch below the bifurcation of the aorta, and therefore on the lower part of the body of the IV lumbar vertebra—continuing upwards the line of the left common iliac vein. The left common iliac artery crosses the lowest part of the vena cava.

Passing upwards on the left side of the spine, it receives opposite the line of the second lumbar vertebra the left renal vein; and a little below this, a small accessory renal vein, which has been joined just before its entry into the main vena cava by the left spermatic vein.

The vena cava then comes forward and crosses the aorta on the level of the first lumbar vertebra, and on reaching the right side of the spine receives the right renal vein about 2 inches above the level of the entry of the left renal. This vein is joined close to its termination by the right spermatic vein.

The vena cava passes on thence, having its ordinary relation to the canal opening in the diaphragm. This case is one of the uncommoner varieties of the vena cava, and can be explained as the others can by reference to the development of the veins of the lower extremities. The ordinary vena cava consists in the abdomen of two separate elements—which are fused at the level of the renal veins. The upper part of the cava from the renal to the diaphragm is the trunk which springs from the sinus venosus in the embryo to return blood from the Wolffian bodies, and is therefore primitively a renal vessel. The lower part consists of the right cardinal vein, whose lower part, the right internal iliac, combines with the vein from the right lower limb into a common trunk which usually passes up on the right side of the aorta, as far as the renal vein, and then

communicates freely with it. Further forwards the posterior cardinal aborts.

Primitively, the left posterior cardinal follows a similar course and communicates with the left renal, but usually a free communication takes place between the right and left cardinal veins, behind the right common iliac artery, forming part of the left common iliac vein.

Traces of the primitive condition may exist in various forms. As in this case, the left posterior vein may persist instead of the right, and then the left posterior cardinal vein flows into the left renal vein, whence the conjoined trunk passes across the aorta to the usual position of the upper renal portion of the inferior vena cava. More commonly, however, both venæ cardinales are persistent either equally dividing the blood from the lower limbs, or one of the two remaining as a mere branch of communication between the renal and the common iliac veins, or, as a result of abortion of the renal vein, the blood from the kidney of one side may pass down the posterior cardinal, and the renal vein open in the common iliac.

Another feature which is not very common is the accessory renal vein found in this specimen. The vein, as usual in such cases, receives the spermatic.

Dr H. D. ROLLESTON read a paper on *Duodenal pouches*, a report of which will appear in the next *Proceedings*.

Professor ALEC FRASER showed several photographs of *human and other vertebrate embryos (external form and in section), and serial sections of adult mammalian brains*. He also described, with Dr NORMAN, *a Case of Porencephaly*, illustrated by photographs of natural size.

Professor A. MACALISTER's paper on *the Axis* will be found *in extenso* in the *Journal of Anatomy and Physiology*, p. 257, January 1894.

## PROCEEDINGS OF THE

# ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

## FEBRUARY 1894.

An Ordinary Meeting was held on Tuesday, February 6th, at University College, London. Present—Professor D. J. Cunningham F.R.S. (President) in the chair, fifteen members and thirteen visitors.

The minutes of the previous meeting were read and confirmed.

The following nominations for membership were announced:—E. P. Paton, M.D., F.R.C.S., Assistant Demonstrator of Anatomy at St Bartholomew's Hospital, proposed by H. J. Waring, C. B. Lockwood, W. McAdam Eccles; Prof. A. C. Haddon, M.A. (Cantab.), proposed by D. J. Cunningham, G. B. Howes, Percy Flemming; C. R. Browne, M.D., proposed by D. J. Cunningham, H. St John Brooks, Percy Flemming; Charles Gibbs, F.R.C.S., Demonstrator of Anatomy at Charing Cross Medical School, proposed by Stanley Boyd, F. C. Wallis, H. F. Waterhouse; Miss A. F. Piercy, M.B. (Lond.), Demonstrator of Anatomy in the London School of Medicine for Women, proposed by Stanley Boyd, D. J. Cunningham, Alex. Macalister; Mrs Percy Flemming, M.D. (Lond.), Demonstrator of Anatomy in the London School of Medicine for Women, proposed by Stanley Boyd, D. J. Cunningham, Alex. Macalister.

It was proposed by the President, seconded by Mr Clement Lucas, and carried, that a Committee be appointed to consider the Report of the Committee of the German Anatomical Society on Anatomical Nomenclature; the committee to consist of Professors Thane, Arthur Thomson, Alexander Macalister, and Sherrington, with the honorary officers of the Society.

In moving this resolution the President said:—

I have no doubt that it is within the knowledge of the great majority of the members of this Society that three years ago, during

the meeting of the International Medical Congress in Berlin, the Anatomical Association of Germany appointed a committee for the purpose of constructing a uniform and homogeneous anatomical nomenclature.

To some extent this committee may be considered to be international, seeing that of the fourteen members who compose it, there are three British anatomists, and several from other countries.

The necessity for the adoption of a uniform scheme of nomenclature is more felt in Germany than in this country. Professor Krause tells us that to some extent each German university may be considered to have a terminology of its own, and that even in one university two systems of nomenclature may be found to exist.

In this country the condition of affairs is not so bad. It is true that in Ireland we have been somewhat eccentric in this respect, and have shown a preference for a terminology of our own, but the great mass of British anatomists have followed with tolerable closeness the terms which have been employed by the editors of *Quain's Anatomy* —the text-book which for so long has very properly taken the lead in matters of this kind.

But our ambition should extend beyond the attainment of a mere national uniformity. The interests of anatomy would be greatly advanced if we could arrive at an international uniformity, and it appears to me that at the present time we have an opportunity of taking a very decided step in this direction.

After an infinite amount of labour, the chief part of which has been borne by Professor Krause, the German Anatomical Association has issued four reports which contain the selected terms for the muscles, bones, joints, and blood-vessels. Additional reports dealing with the other systems will follow in the course of time.

The rules which were formulated for the guidance of the Committee in their selection of terms were admirably conceived. The Committee was instructed to be conservative in the widest sense; to show a preference for a single Latin name for each part of the body; to avoid as far as possible personal, speculative, and descriptive terms; to be careful to be correct both from a linguistic and an orthographical point of view, &c., &c.

It would be out of place for me to criticise at the present moment the terms which have been already adopted by this committee; but I may be allowed to say that in my opinion they have been chosen with great care and judgment. It is true that several imply methods of description and ways of looking at things which would not altogether be approved by many of us in this Society, and in this consists our great difficulty, because it would be wrong to advocate a system which would in any degree lessen our own individuality as British Anatomists. But I think I am right in saying that the great majority of the selected names might be formally adopted by us, and even this would be a great advance towards establishing an international uniformity.

I beg to move, therefore, that a Committee consisting of Professors

Macalister, Thane, Sherrington, and Thomson, together with the honorary officers of this Society, be appointed to consider the nomenclature which has been adopted by the German Anatomical Society, and to report to the Society how far it would be possible for the Anatomical Society of Great Britain and Ireland to adopt this nomenclature as its own.

The following gentlemen were declared duly élected Members of the Society:—H. B. Grimsdale, B.A., M.B., Demonstrator of Anatomy, St George's Hospital; R. C. Bailey, M.S., F.R.C.S., Assistant Demonstrator of Anatomy, St Bartholomew's Hospital; G. B. M. White, M.B., B.S., F.R.C.S., Demonstrator of Anatomy, University College, London.

Mr W. M'Adam Eccles showed a specimen of *Bifurcation of Rib and Costal Cartilage* obtained from a boy aged 16 years, well developed for his age, and without any other noticed deformities.

The third rib of the left side was abnormally broad, being fully 1 inch in width towards its anterior extremity, where it bifurcated, the upper branch measuring $\frac{2}{5}$ inch and the lower $\frac{1}{2}$ inch wide.

The branches were attached to a bifurcated costal cartilage, $1\frac{1}{2}$ inch of which was undivided, and it appeared to be attached in the usual manner to the sternum. The oval space thus inclosed was filled across with a thin fibrous membrane, from which some of the fibres of the pectoralis major arose. The pleura passed over it behind.

There was no attempt at any fusion of the ribs on the left side, which were normal in number, and other respects.

On the right side the ribs and cartilages were normal, except that the 5th costal cartilage had a lateral branch extending for $1\frac{1}{4}$ inches upwards, ending in a sharp extremity, which was not attached to the cartilage above.

There was no other abnormality found in the osseous system.

Testut, in his work, mentions bifurcation of ribs as not being a very rare occurrence, and speaks of the oval aperture here mentioned.

Prof. Humphry, in his work, alludes to bifurcation, but gives no explanation of the condition.

Mr Black showed a similar specimen.

The President, Prof. Cunningham, gave a lantern demonstration of the development of certain of the cerebral furrows. In the course of the demonstration he remarked that he was under the impression that (1) the local exuberance of growth on the cerebral surface, which results in the formation of a gyrus, has a deep physiological meaning; (2) the greater energy of growth which is usually exhibited by the ascending parietal convolution, when compared with the ascending frontal, may also have a physiological significance; and (3) the deep horizontal gyrus in the fissure of Rolando—indicating, as it does, the place of union of its two originally separate parts—may, as sug-

gested by Professor Purser, have some relation to the division of the motor area into a leg and arm district.

Professor SCHÄFER remarked that it is well known to those who have studied the localisation of functions in this part of the brain, that the ascending parietal convolution has not by any means the same physiological importance as the ascending frontal, seeing that the posterior border of the gyrus is frequently entirely inexcitable in monkeys, and that the number and complexity of the movements evoked by excitation along the middle of the gyrus and along its anterior border are much more limited than those obtainable from the ascending frontal gyrus. Further, in the very large number of monkeys, of different kinds, in which he had had occasion to study the localisation of function in the cortex, he had not found, except in the case of the occipital operculum, the Sylvian fissure, and the sulci bounding the limbic lobe, that any of the markings on the surface of the brain form constant physiological landmarks. Movements of the same part of the body may be got by excitation on either side of even such a deep and important fissure as the Rolandic, and the same applies in his experience to all the fissures which are included within the so-called motor region of the cortex. And if the development of the Rolandic fissure in two parts were due to the physiological cause suggested by Professor Cunningham, it seems difficult to see why there should not be a similar subdivision at the junction between its middle and lower thirds, where the arm and face areas abut against one another.

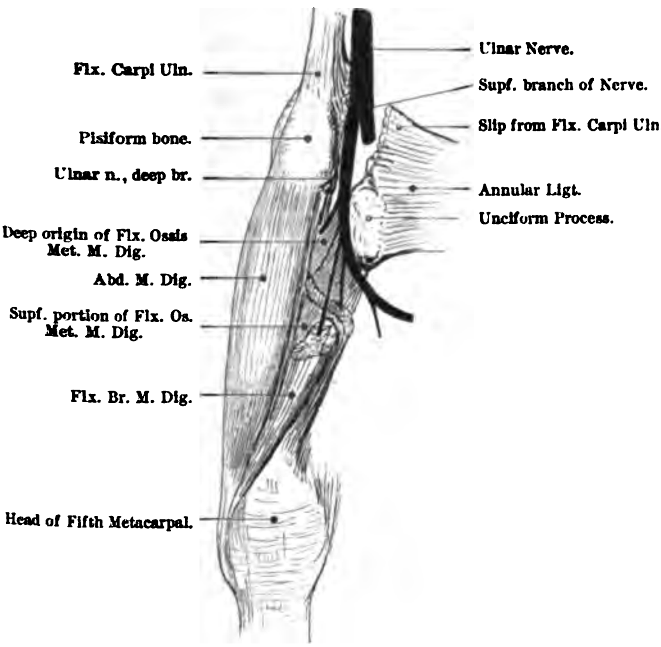
Professor HORSLEY made some remarks on the special bearing which Professor Cunningham's exceedingly valuable observations had upon the topographical functions of the cortex of the brain. He thought that the observations on Man as well as on the Anthropoids absolutely confirmed Professor Cunningham's view that the level of the superior genu of the fissure of Rolando marks the separation between the lower limb and the upper limb areas. He then went on to point out that the various areas in the cortex for the representation of different parts of the body are not bounded by sulci which run transversely to the long axis of the hemisphere, but parallel, and that the areas in question frequently cross transverse sulci, even such an important one as the fissure of Rolando.

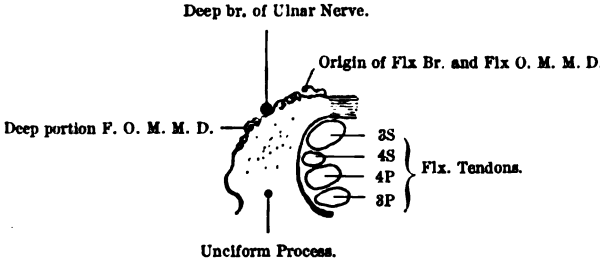
Mr WILLIAM ANDERSON read *A Note on the Course and Relations of the Deep Branch of the Ulnar Nerve.*

The frequency of wounds in the region of this nerve, and the serious consequences of a paralysis of the muscles it supplies, will justify the addition of any details elucidating its course and relations.

The account given in our leading text-book is as follows:—"The *deep part* turns backwards with the deep branch of the ulnar artery between the abductor and flexor brevis minimi digiti muscles, and follows the course of the deep palmar arch across the hand."

It will be shown that the most important segment of the tract is here very loosely indicated. A careful examination will demonstrate that the relations of the nerve in the interval between the origin of the abductor minimi digiti and the deep palmar arch are so well defined that the course may be readily followed even in such difficult




dissections as those which are performed under the usual surgical conditions upon mutilated, inflamed, or cicatricial structures.

The ulnar nerve breaks up into its superficial and deep terminal divisions on entering its fibrous channel between the front of the anterior annular ligament and the slip of insertion sent to the ligament by the tendon of the flexor carpi ulnaris. The deep branch

runs on with its companion vessels in contact with the radial surface of the pisiform bone, often grooving it, and then dips in between the abductor and flexor brevis minimi digiti. Beyond this point it comes into relation with the ulnar side of the unciform process of the unciform bone, piercing the fibres of origin of the flexor ossis metacarpi minimi digiti, and sometimes casually grooving the process near its free extremity. In this situation it gives off twigs to the hypothenar muscles. Finally, it curves in a radial direction around the distal side of the bony hook to join the deep palmar arch.

From this it will be seen that the deep branch may be found either against the radial side of the pisiform bone, or on the ulnar side of the unciform process near its tip; and as both of these landmarks are easily detected, there should be no difficulty in tracing out the nerve under any ordinary surgical conditions.

Shortly after having observed these relations, an opportunity presented itself by which I was able to put the knowledge to a practical use. A girl aged 14 was admitted into St Thomas's Hospital on Nov. 4, 1892, the left wrist having been crushed in a calender machine. There was evidence of paralysis of both ulnar and median nerves, but the crushed parts were sloughing and suppurating so extensively that it was not judged advisable to interfere until a more healthy condition had been established. It was not until over four weeks later that the processes of repair were sufficiently advanced to allow operation. A dissection was then made from the upper limit of the point of injury, and the trunks of the ulnar and median nerves were readily found, the former torn across, the latter crushed by a fractured and displaced unciform process. The distal end of the deep branch of the ulnar nerve could not be seen in the midst of the altered tissues, but on dissection over the ulnar side of the broken unciform process it was discovered in the position that has been described, and was sutured to the proximal segment. The operation was successful, and the girl has regained good use of the hand and fingers.

Mr Arthur Keith read a paper on the *Flexor longus pollicis and Flexor longus hallucis* in the Catarrhini, and also a note on the *Supracostalis* muscles, which will be found printed *in extenso* in the *Journal of Anatomy and Physiology*, page 335 and page 333 respectively.

Dr Rolleston showed *two specimens of duodenal pouches.*

Just above the opening of the biliary papilla on the duodenum a pouch about the size of a walnut came off from the left or median side of the intestine.

The pouch was lined by normal mucous membrane, and passed into the substance of the pancreas, in which it was embedded.

The common bile duct and pancreatic duct were of the normal size and quite healthy, and were in close contact with the pouch, by which they were displaced towards the median line.

The normal condition of these ducts proved that the pouch was not, as might have been thought, a dilated "ampulla Vateri."

These specimens were shown in order to obtain an expression of opinion as to the probable cause of these pouches.

Two views suggest themselves: (1) That the pouches are pathological, and are due to ulceration at some past time, and subsequent bulging from weakening of the wall of the gut. It should be stated that in one of these cases an old scar was found in the stomach—evidence of a past gastric ulcer. There was, however, no sign about the pouches of any ulceration, cicatrices, or past inflammation: ulceration of the duodenum is almost limited to the first part of the duodenum, while these pouches are near the end of the second portion. The median wall of the duodenum in the situation of these pouches is again so well supported by the pancreas that it would appear unlikely that a diverticulum would readily result from ulceration.

The walls of these pouches have been examined microscopically and are found to contain muscular fibres in bundles.

(2) That the pouches are diverticula, due to irregularity in the process of development. Their situation in the duodenum, in the immediate vicinity of the diverticula, which pass off in fœtal life to form the liver and pancreas, is very suggestive, and makes the writer incline to this view.

Mr Targett agreed with the suggestion that the duodenal pouch was probably developmental in origin. He had met with diverticula of that part of the intestine, some of which were undoubtedly pathological. But in one instance the specimen exactly corresponded with that shown by Dr Rolleston. There was a globular pouch, an inch in diameter, situated by the side of the biliary papilla. The mucous membrane lining the sac was normal, and its thin wall was only connected to the surrounding parts by loose tissue. The patient was an old woman who had died after an operation for strangulated hernia. He thought it was necessary in the consideration of such preparations to exclude sacculi or hernial protrusions of the mucous coat, which were prone to occur where the continuity of the muscular coat was broken by the entrance of large vessels and ducts. Thus sacculi of the intestine were always along the mesenteric border, where the mesenteric vessels entered the wall of the bowel; and in the bladder they were most commonly met with at the ends of the ureters or urachus, where the ducts perforated the wall of the viscus.

Professor G. B. Howes remarked that the study of the comparative morphology of the pancreas showed that the existence of more than one pancreatic duct in the adult is a more widely distributed feature than had been hitherto supposed; and that the recent investigations of Göppert, v. Kupffer, Felix, Stöln, and others were bringing us towards the conclusion that the pancreas is, in all classes of vertebrata, a compound organ, derivative of from one to four diverticula (and

mostly from three, as appeared to be the case in Man himself). When first found, these diverticula are widely open like Dr Rolleston's duodenal pouches; and he viewed the latter with a strong suspicion that the two sets of structures would be found to possess further features in common. The fact of the "pouches" being apparently muscle-clad appeared to him no argument against this view, as the pancreas of certain fishes (ex. Protopterus) is known to lie wholly within the musculature of the intestinal wall.

# PROCEEDINGS OF THE

# ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

## MAY 1894.

The Annual General Meeting was held on Monday, May 21st, at Middlesex Hospital. Present—Mr Lockwood (Vice-President) in the chair, Sir G. M. Humphry (Past-President), eighteen members and fourteen visitors.

The minutes of the previous meeting were read and confirmed.

A letter was read from the President, expressing his regret at being unable to be present.

The following candidates were declared duly elected Members of the Society:—E. P. Paton, M.D., F.R.C.S., Assistant Demonstrator of Anatomy at St Bartholomew's Hospital, proposed by H. J. Waring, C. B. Lockwood, and W. M'Adam Eccles. Prof. A. C. Haddon, M.A. Cantab., proposed by D. J. Cunningham, G. B. Howes, and Percy Flemming. C. R. Browne, M.D., proposed by D. J. Cunningham, H. St John Brooks, and Percy Flemming. Charles Gibbs, F.R.C.S., Demonstrator of Anatomy at Charing Cross Medical School, proposed by Stanley Boyd, F. C. Wallis, and H. F. Waterhouse. Miss A. F. Piercy, M.B. Lond., Demonstrator of Anatomy in the London School of Medicine for Women, proposed by Stanley Boyd, D. J. Cunningham, and Alex. Macalister. Mrs Percy Flemming, M.D. Lond., Demonstrator of Anatomy in the London School of Medicine for Women, proposed by Stanley Boyd, D. J. Cunningham, and Alex. Macalister.

Sir G. M. Humphry made the following remarks with reference to the terms *Flexion and Extension of the Ankle.* The *ankle* being a rectangular hinge joint, with the leg and foot at right angles in mid-position, the terms "flexion" and "extension" are scarcely appropriate to it, forasmuch as the expansion of the angle on the one side is attended with an equal contraction of that on the other side. Granting, however, the terms, the raising of the heel, which takes place in concert with the other flexor movements of the limb, which is effected by muscles and nerves segmented from the flexor aspect of the limb, and associated in the flexor movements of the knee, tarsus and toes, and which corresponds with the flexor movement of the wrist, seems rather to require that the term *flexion* should be applied to it. Moreover, the raising of the fore part of the foot, which takes place in concert with the other extensor movements of the limb, which is effected by muscles and nerves segmented from the extensor aspect,

and associated in the extension of the tarsus and toes, and which corresponds with the extension of the wrist, seems to require that the term *extension* should be applied to it.

The application of the terms in present use has been derived from the apparent straightening of the limb when the toes are lowered, and derives some support from comparative anatomy. It is well, however, to consider, now and then, the grounds for the usage of these and other terms in anatomy.

Professor THANE was unable to agree with the conclusions of Sir George Humphry as to the use of the terms *flexion* and *extension* at the ankle-joint. It is true that the foot in the position of rest is more or less at right angles with, and projects both in front of and behind the bones of the leg. But the two projections are not of equal value. The axis of the limb is continued in the anterior projection, and the projection of the heel is a secondary prominence, which does not occur in the primitive form. The angle between the leg and the fore part of the foot is therefore the angle to be considered: a diminution of this angle is *flexion*, and an increase of this angle is *extension*, in accordance with what would universally be understood by "straightening the foot upon the leg." The terms *flexion* and *extension* are physiological terms, and it is desirable that they should be used only in a physiological sense. The direction in which the bending at a given joint takes place is determined by the functional requirements of the part. In the upper limb all the joints are bent in the same direction, in accordance with the use of the limb as a grasping organ. In the lower limb the large joints are bent alternately in opposite directions, that arrangement being the most convenient for the shortening of a column of support. For morphological indications the terms *dorsal* and *ventral* should be used. Flexion of one joint may take place to the ventral side, of another to the dorsal side. Flexion may in one case be performed by ventral muscles, in another case by dorsal muscles, and in a third case by both. The ankle-joint, for example, is flexed wholly by dorsal muscles, while it is extended mainly by ventral muscles, but in part also by muscles of dorsal origin (*peroneus longus* and *brevis*).

The Secretary read for Professor MACALISTER *A few Suggestions on Anatomical Nomenclature*:—

Now that our President has taken action in the endeavour to procure uniformity in anatomical nomenclature, there is some prospect of reform; and whether ultimately the scheme of the German Committee be adopted or no, it is earnestly to be hoped that British anatomists will have sufficient *esprit de corps* to fall in with whatever carefully-considered system may be finally agreed on by the Anatomical Society.

While the question is still pending there are a few suggestions in the direction of simplification and of definiteness which I would throw out for the consideration of the Society:—

1. It is remarkable that, while the blood-vessels of all parts of the alimentary canal are named on a uniform plan, those of the rectum should be called by names which are inaccurate and troublesome for

the student to spell. We have happily banished "coronaria ventriculi" from our teaching, and speak of the "gastric" artery: why should we not banish "hæmorrhoidal," and speak of rectal vessels? The superior artery of the rectum has no possible connection with hæmorrhoids; and surely, when there is for the other portions of the intestine, and the parts related to them, a simple method of nomenclature uniformly adopted, it is very bad construction to build the names of these upon piles.

2. While anatomists have generally erred in the direction of multiplying names, it is singular how some parts have escaped and are still nameless. Take, for example, a region of great interest to the surgeon, the lower end of the radius; here there are a series of constant features which have not received definite names. There is (1) the ridge which limits the insertion of the pronator quadratus externally; (2) the ridge which limits the anterior concavity for this muscle below, and which separates it from the oblique ligamentous area on the palmar surface of the styloid process. Simple names for these, such as I suggested some years ago, "pronator crest" and "epiphysary crest," or something like these, would save periphrasis in description.

Then there are the four grooves on the back, and the three tubercles which subdivide them: we have no system of proper names for these. I suggested for these the names respectively of "1st, 2nd, 3rd, and 4th thecal sulci," and "internal, middle, and external thecal tubercles." Whether these be adopted or no is immaterial; I am only concerned that some definite, simple set of names should be applied to those parts, so that in at most three words each exact spot may be indicated in description.

The Secretary read for Mr DIXON a Note on *A Method of Microscopic Reconstruction*:—

Last summer, while working in the laboratory of Prof. His in Leipzig, a method of microscopic reconstruction was shown to me by Prof. His which proved to be most useful in tracing the development of nerves in the embryo. The method has, I believe, so far only been employed by Prof. His himself, and that only to a small extent. Instead of the wax plates usually used in construction, plates of glass covered with some transparent varnish are made use of. The drawings of the serial sections having been made with a camera lucida, are traced on to the varnished sides of the glass plates, and the model is built up simply by superimposing the plates.

In such models made up of drawings on glass plates, when viewed by transmitted light, the course of even such fine nerves as the vidian and the nerve of Jacobson in the embryo of seven weeks can be made out, and their connection determined. One great advantage of the method is, that the model can at any time be taken to pieces and the separate drawings examined. This proves most useful in following nerves when crossing or sudden changes in direction take place. If any mistake in one of the plates of the model is found, the coloured inks used in making the drawings can be washed off and a corrected one put in its place.

The thickness of the glass plates used will, of course, be the same multiple of the thickness of the sections as the magnification of the drawings.

Mr Dixon sent a model of a Human Embryo head, showing the Gasserian ganglion and other cranial nerves, to illustrate the above method.

Prof. Thomson suggested that in place of making drawings by the camera lucida, greater accuracy would be secured by employing a projection apparatus, such as is provided by Newton & Co. for use with their lantern, and making negatives either on bromide paper or celluloid films. In the case of the paper, the negatives might be cut in such a way as to remove the absolutely black parts, such as represent clear spaces in the actual section. A certain amount of translucency might then be imparted to the paper print by ironing with paraffin. The prints could then be superposed and a reconstruction effected. In regard to the films, they might be treated as negatives, or positives might be printed from them. The outlines of the object could then be accurately cut out with a knife or pair of scissors, and a reconstruction easily obtained by superposing the films in order. The films are as transparent as glass, and possess the additional advantage that they are thinner and can be cut as easily as paper. Mr Thomson pointed out that, in order to successfully carry out the reconstruction, it would, of course, be necessary to pass the serial sections under the objective of the projection apparatus all under precisely the same conditions, in order to secure a precisely similar amount of amplification in each section photographed. If the sections were all magnified alike, it mattered not if their position on the film or paper was relatively the same, for, by trimming them as suggested above, they would, if the above precautions had been taken, be found to keep sufficiently accurately for all practical purposes. He was making a series of experiments in this direction, and might be able at some future time to submit his results to the Society.

Mr T. W. P. Lawrence remarked upon the *position of the Optic Commissure* in relation to the sphenoid bone. In some recently observed specimens, the commonly accepted position of the commissure upon the optic groove was departed from; and although the number of cases examined was too small to justify the statement that the commissure never lies upon the optic groove, Mr Lawrence expressed the belief that such will be found to be the case. No preparations of any but fresh specimens, and made with special reference to this point, could be considered of value. Figs. 1 and 2 are sketches of preparations so made, the head being held vertically, and only so much of the brain substance being removed as would expose the commissure and its immediate surroundings, and the connection of the commissure with the rest of the brain being undisturbed. In neither of the cases was there any intra-cranial disease.

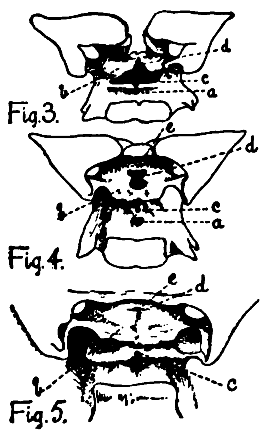
Fig. 1 is from a girl aged 4½ years. Here the commissure is placed far back from the optic groove and olivary eminence, so that a large part of the upper surface of the pituitary body is visible in front of it. Fig. 2 is from a man. Here the commissure almost entirely

covers the pituitary fossa, its anterior border very nearly corresponding with the posterior border of the olivary eminence; but it does not touch the latter, and, as in the last case, is quite removed from the optic groove.

The development of the olivary eminence can be seen from figs. 3, 4, and 5, the last from the specimen first described (fig. 1). At *a* is a canal in the middle of the basi-sphenoid (canalis cranio-pharyngeus); in front of this, in fig. 3, is a large triangular interval, its base bounded by basi-sphenoid, its two sides by pre-sphenoid. By the growth inwards, from each side, of the hinder part of the pre-sphenoid (fig. 3*b*), this interval is divided into two unequal parts: the posterior part (fig. 4*e*) takes the form of a small canal lying between pre- and basi-sphenoid, the anterior and larger part (fig. 4*d*) lying wholly in the pre-sphenoid. The latter gradually closes from behind forwards to a minute canal (fig. 5*d*). There may thus be present, at one stage of development, three foramina in the middle line, of which the anterior (fig. 4*d*) may, for the moment, be called the pre-sphenoid foramen. (The presence of the pre-sphenoid foramen in young bones was first brought to Mr Lawrence's notice by Prof. Thane: it is occasionally present in adult bones, leading into a vertical canal passing for a distance sometimes of nearly ½ inch into the sphenoidal septum.) The space anteriorly between the orbito-sphenoids is filled up by the growth forward of the pre-sphenoid bone


Fig. 1.


Fig. 2.




(figs. 3 and 4). The pre-sphenoid foramen serves to mark off the anterior from the posterior part of the pre-sphenoid bone; and it will be seen from fig. 4 that the groove (*e*) running across the bone from the inner angle of one optic foramen to the other lies on the anterior part. This groove, which for the moment may be called the primary optic groove, is bounded anteriorly by a margin, in the formation of which the three bones (orbito-sphenoids and pre-sphenoid) take about equal shares; this margin becomes the limbus sphenoidalis of the

adult bone, the anterior limit of the optic groove. The part of the pre-sphenoid bone lying behind the pre-sphenoid canal is developed in a rounded piece of cartilage, overhanging the pituitary fossa somewhat, and ends posteriorly in a ridge which forms the anterior limit of that fossa. At first (fig. 4) the anterior and posterior parts of the pre-sphenoid form about equal parts of the olivary eminence, but, as growth advances, the posterior part (fig. 5*b*) greatly preponderates, while the primary optic groove (*e*) is reduced to a shallow furrow of 2 or 3 mm. or less width, but is usually distinct even in adult bones, especially at the sides, where it may be traced to the upper and inner angles of the optic foramina. In cases where the primary optic groove is reduced to a mere line, while its anterior lip, the limbus sphenoidalis, remains prominent, it takes the form of a slit-like sulcus lying across the front of the olivary eminence, and laterally the approximation of the lips may go on to complete fusion, and the groove be converted into a canal in part of its course. On the other hand, if that part of the limbus sphenoidalis which is formed by the pre-sphenoid bone is only slightly or not at all marked, as is sometimes the case, the primary optic groove in the adult bone will be almost or quite undistinguishable in its middle part. The posterior portion of the pre-sphenoid bone (fig. 5*b*) and its posterior ridge present great variations in respect of height, width, and antero-posterior measurement.

The presence and form of the optic groove depend upon the degree of development of the several parts above described. If the anterior lip of the primary optic groove remains distinct, this alone will give the appearance of an optic groove; if, at the same time, the posterior part of the pre-sphenoid and its ridge are well developed in vertical height and posterior projection, the optic groove will be well marked. On the other hand, if the anterior lip of the primary optic groove becomes smoothed down and the posterior ridge of the pre-sphenoid bone remains low, an optic groove will be absent, even though the olivary eminence as a whole is large and well developed.

Often, however, a shallow groove is seen in adult bones passing from one optic foramen to the other, across the middle of the olivary eminence, not reaching as far forward as the limbus sphenoidalis, and distinct from the primary optic groove. This groove Mr Lawrence believes to be due to the crescentic fold of arachnoid membrane lying between the optic nerves and bounding the arachnoidal cisterna in that situation.

Mr BLACK showed a specimen of *a divided internal Cuneiform Bone*, and also two specimens of the *Os styloideum*.

Professor THANE showed some specimens of *divided internal Cuneiform Bone*, and also a *Humerus*, showing a well-marked double spiral groove.

Mr F. G. PARSONS read a paper *on the Morphology of the Tendo Achillis*, which is printed *in extenso* in the *Journal of Anat. and Phys.*, p. 414.

# INDEX OF PROCEEDINGS OF ANATOMICAL SOCIETY.

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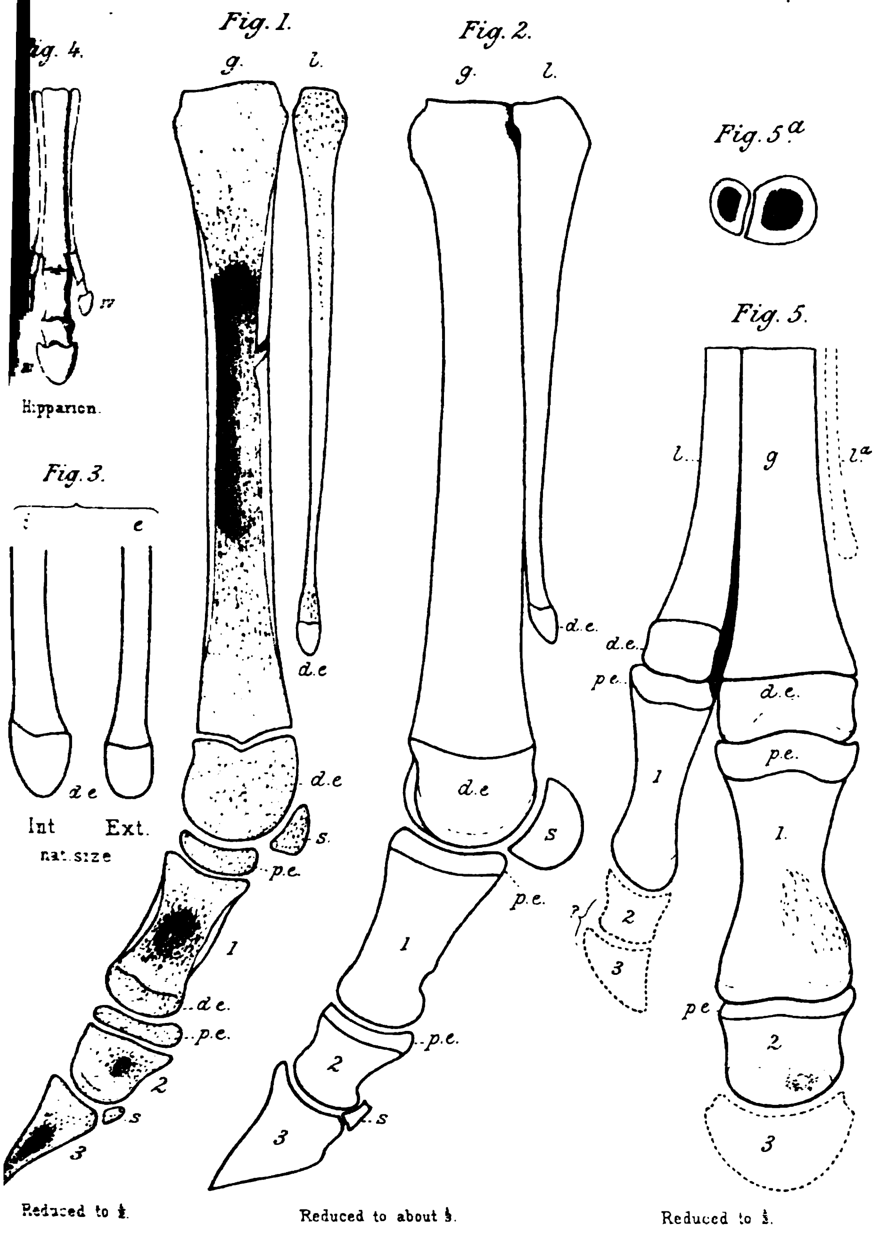


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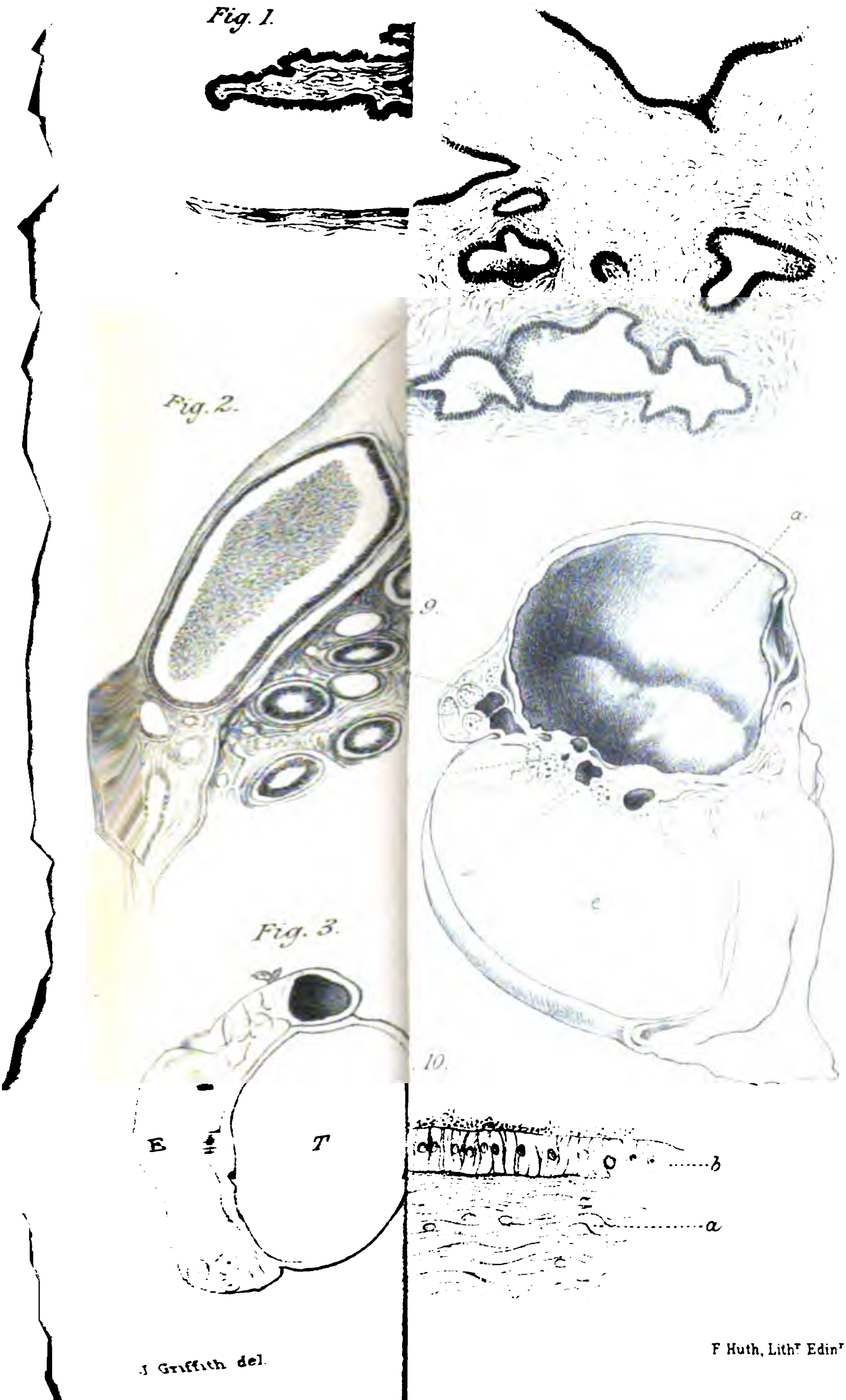
DEVELOPMENT OF THE BONES OF THE FOOT OF THE HORSE.




J Griffith del.

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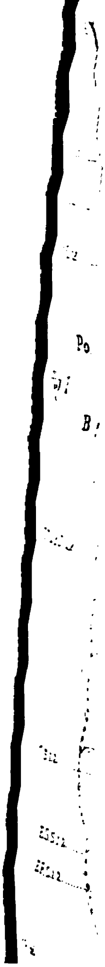

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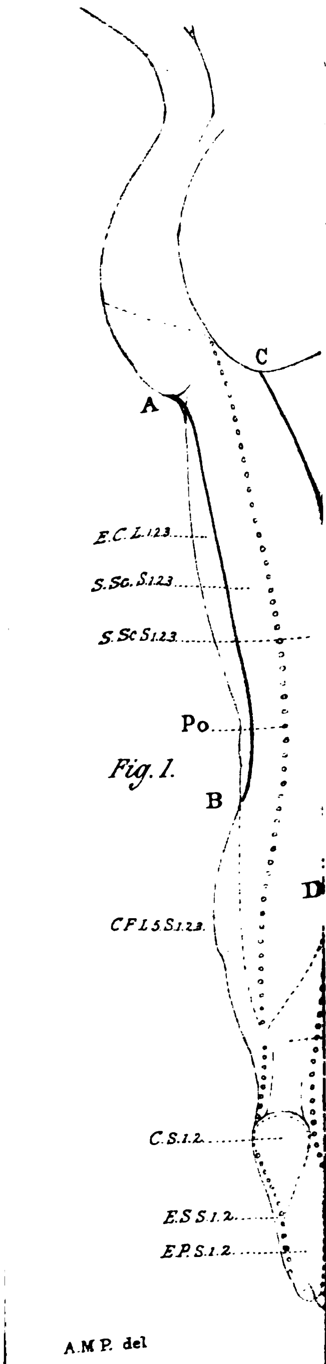


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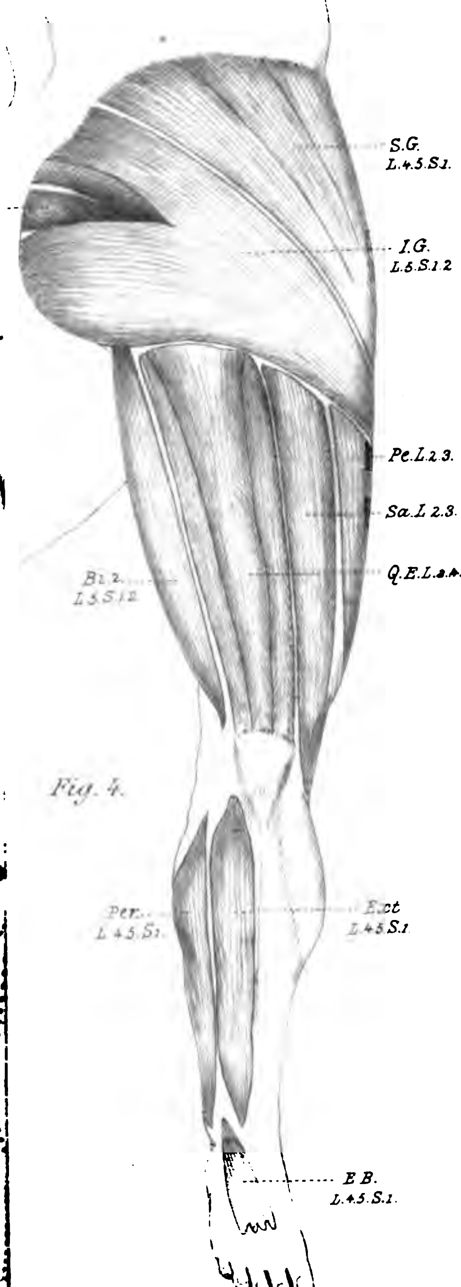


Fig. 4.

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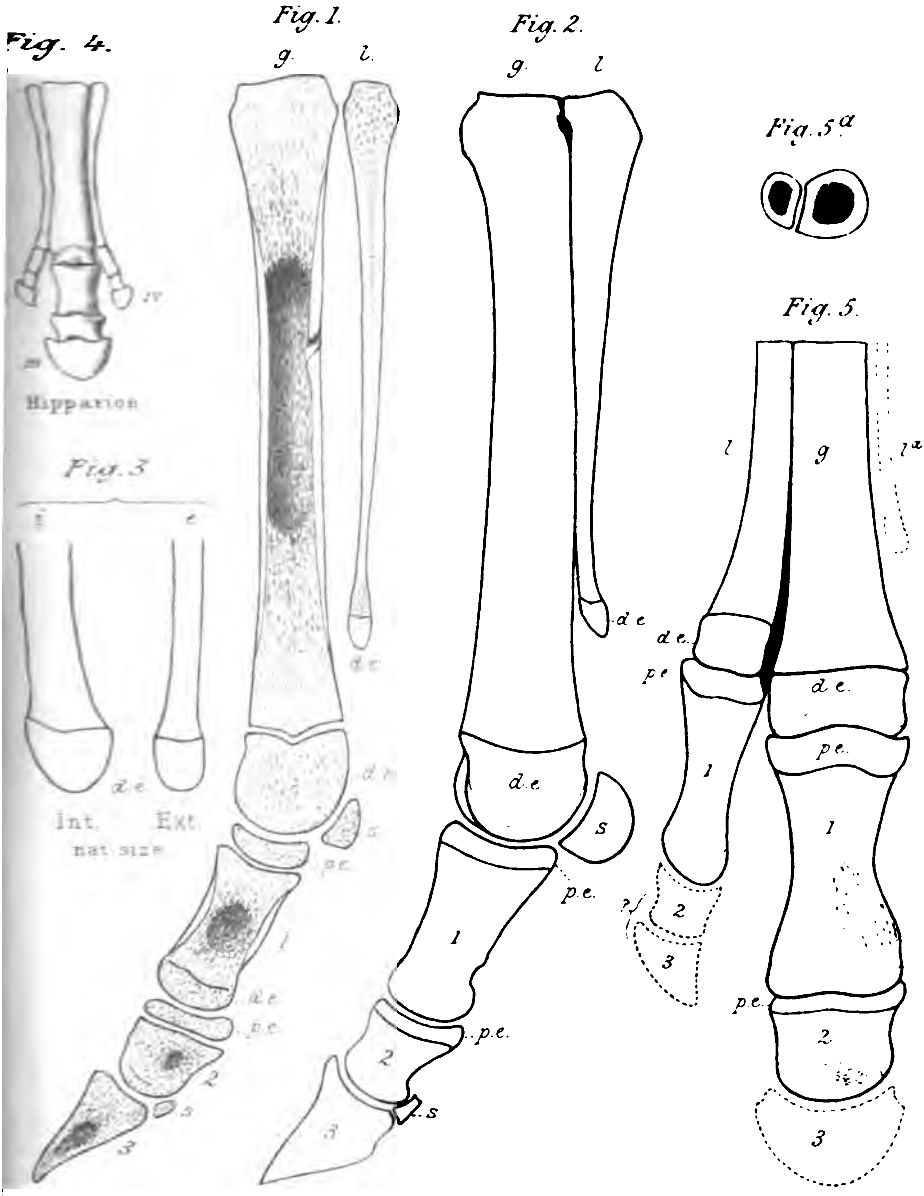


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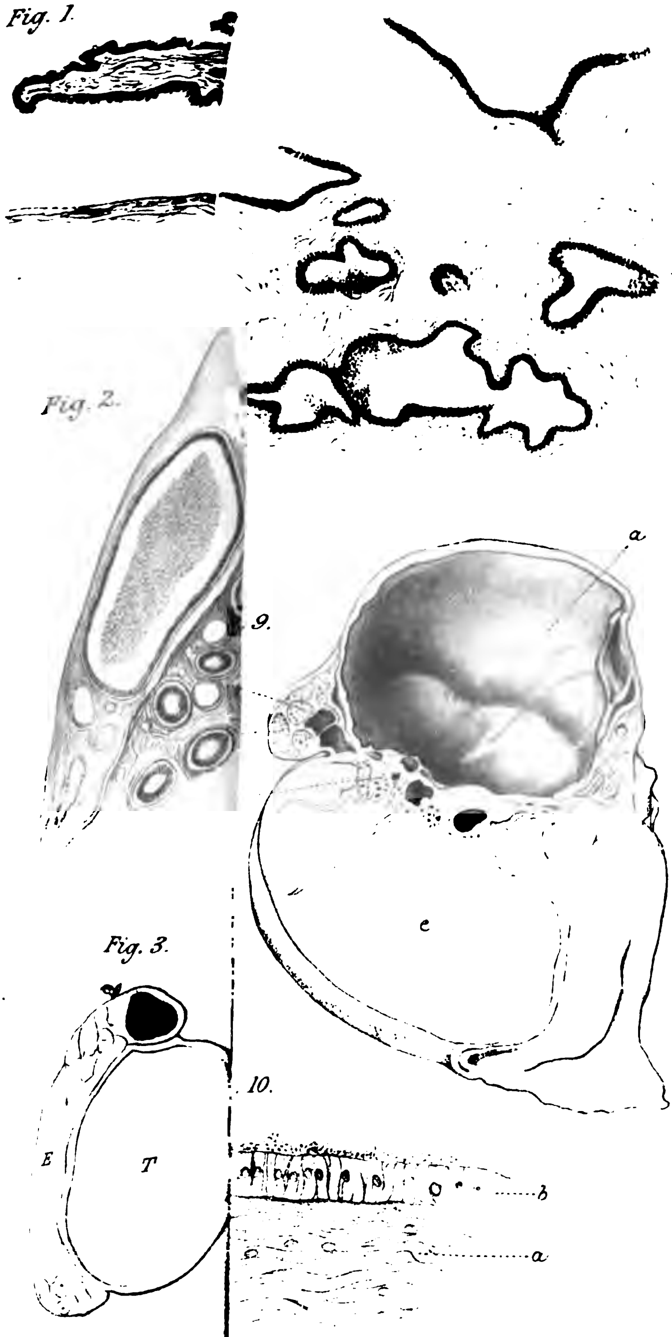
**DEVELOPMENT OF THE BONES OF THE FOOT OF THE HORSE.**

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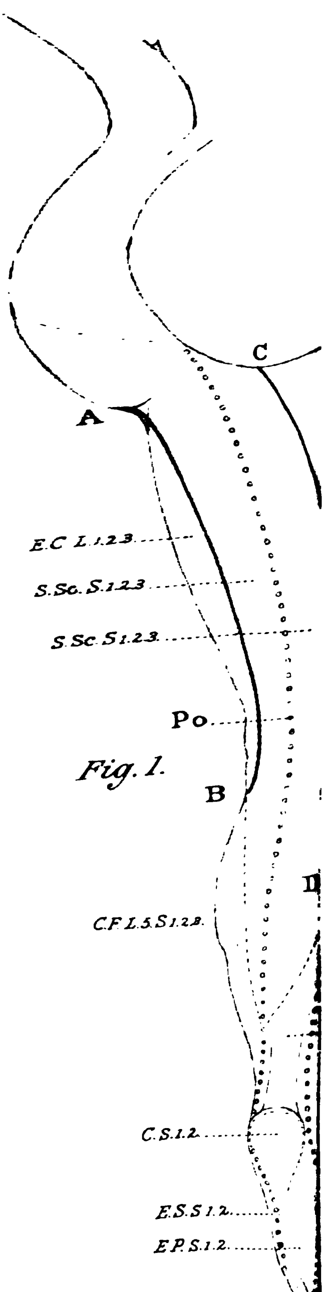


Fig. 1.

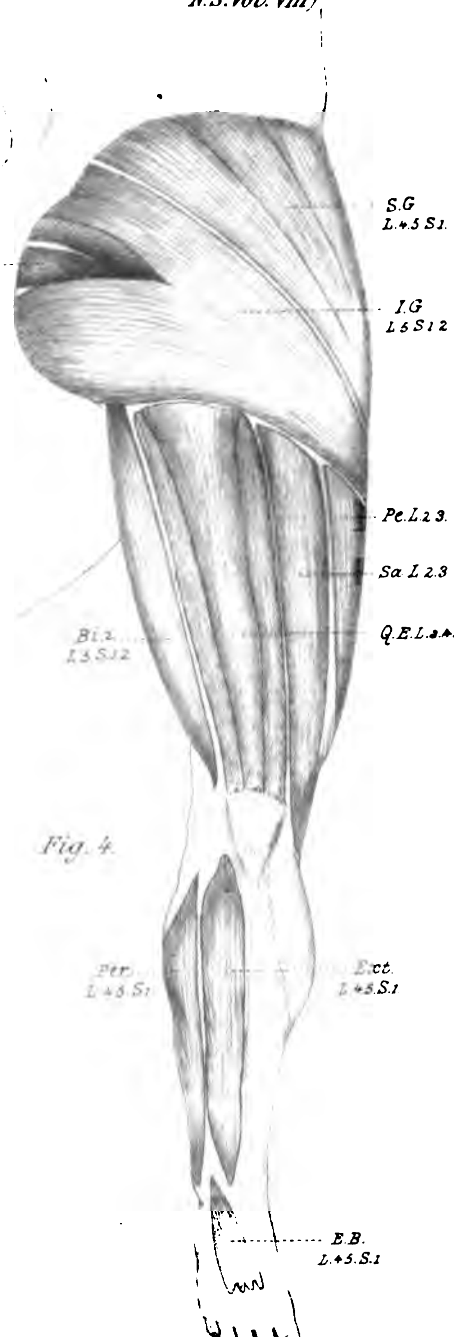


Fig. 4.

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Fig.

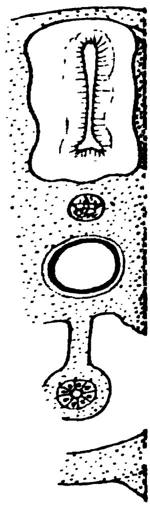

Fig. 6

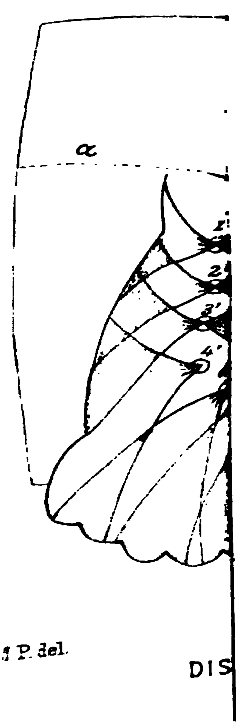


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Fig. 1.

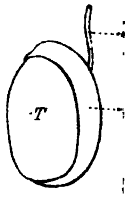



Fig. 5.

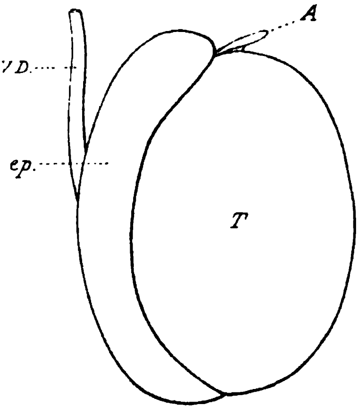



Fig. 2.

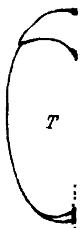
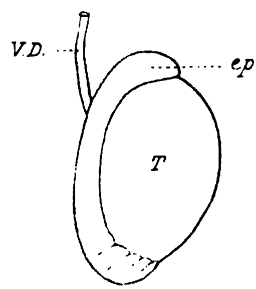



Fig. 9.

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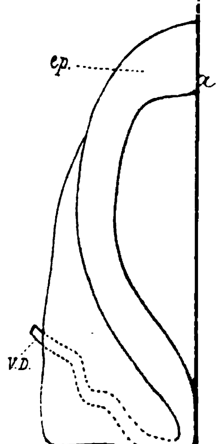
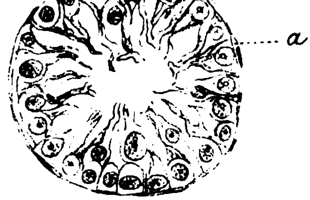


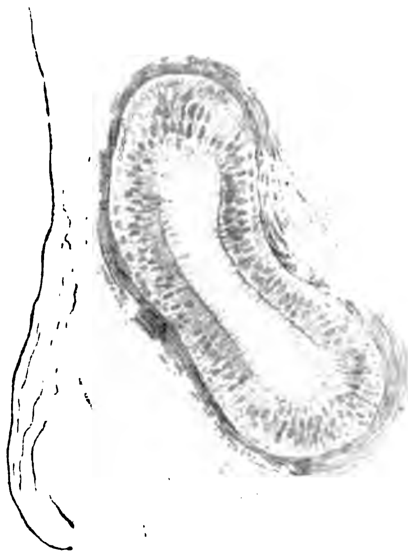

Fig. 11.




J. Griffiths del.

F. Huth, Lith^r Edin^r

Fig. 1.



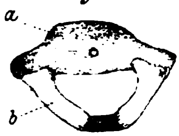
6.

Fig. 2.


J. Griffiths del.

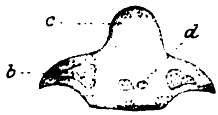
F. Huth, Lith$^r$ Edin$^r$

Fig. 1.



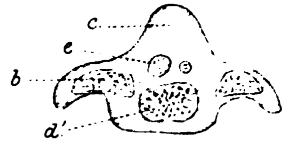

at 11th week upper surface × 5

Fig. 2.



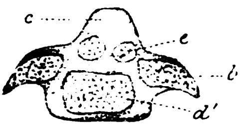

at 16th week coronal section × 2

Fig. 3.



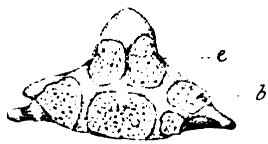

at 19th week × 3

Fig. 4.



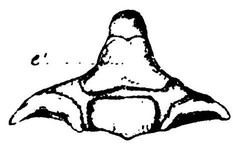

at 22nd week × 1½

Fig. 5.



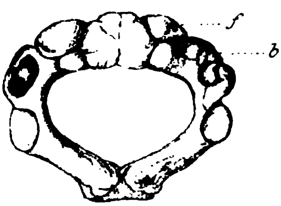

at 5 months after birth × 1¼

Fig. 6.




at birth. × 3

Fig. 7.




Hypochordal epiphysis 15th months.

Fig. 8.


Hypochordal epiphysis 28th months.

Fig. 9.


Apical epiphysis.

Fig. 10.

Coronal section, showing traces of epiphysial plates.

F Huth, Lith^r Edin^r

DEVELOPMENT OF AXIS.

Fig. 11.

Fig. 14.

Fig.

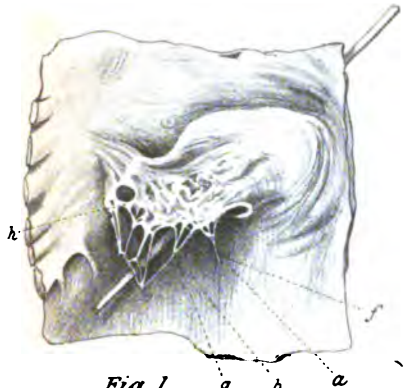



Fig. 1.

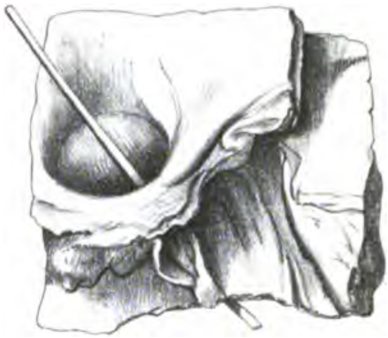


Fig. 2.

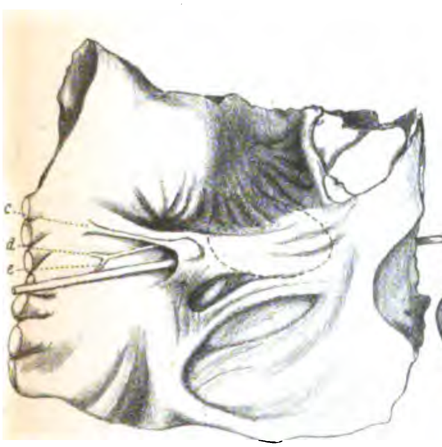



Fig. 3.

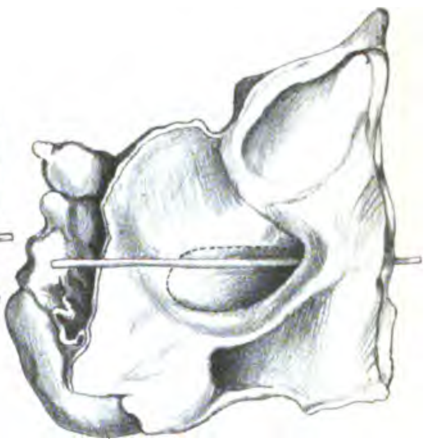
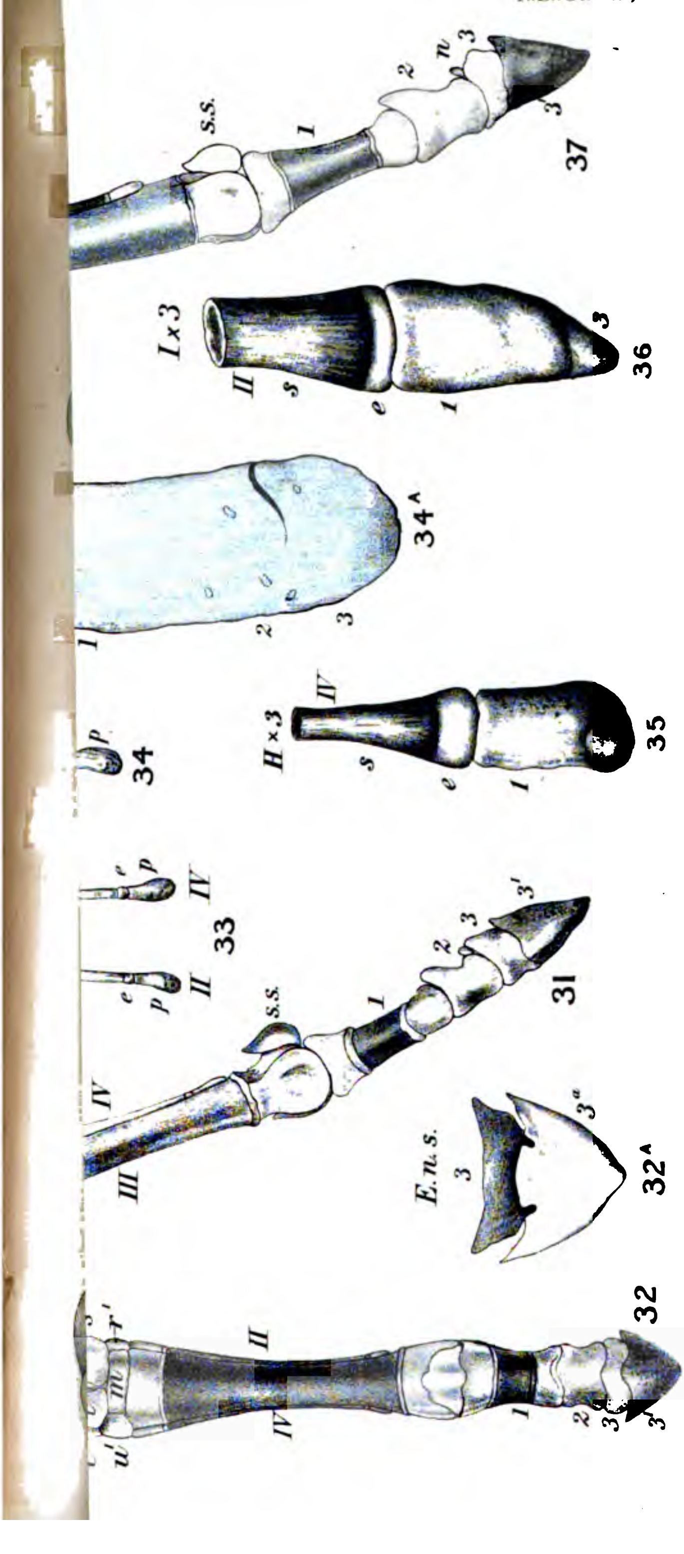


Fig. 4.

Fig. 5.

Wilson, Camb: del. F. Huth, Lith[r] Ed

FORAMEN OVALE IN HEART OF SHEEP.


37
36
I × 3
34A
35
H × 3
34
33
31
E. n. s.
32A
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